From the Author.

SKELETON NOTES

ON

ANALYTICAL CHEMISTRY,

FOR STUDENTS IN MEDICINE.

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EXTRACTED FROM THE FIFTH EDITION OF 'NOTES FOR STUDENTS IN CHEMISTRY.'

BY

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PREFACE.

In re-casting my 'Notes for Students in Chemistry,' the sixth edition of which was published by Messrs. Churchill in 1878, I found myself so cramped for space that I omitted the Skeleton-notes on Analysis. Although, at the time, I had the full intention of reproducing them, business has prevented me to such an extent, that I had almost resolved to allow them to drop. But, partly pressed by my own pupils, partly and chiefly on the solicitation of my Colleague in Examinations, Dr. George Harley, F.R.S., I have reconsidered the matter. The result is the separate edition.

In passing the sheets through the press, I have to express my sincere thanks to my able Assistant Mr. C. G. Stewart.

If I do not entertain the same opinion as to the employment of Analytical Tables, as do some of my brethren, it is because of the ludicrous mistakes occasioned by their improper employment. It is true that our students in medicine have not much time to devote to the study of practical Chemistry, and that the requirements of the College of Surgeons are nearly *nil:* but, at the School of St. Thomas's Hospital, we take our stand upon the Examinations of the University

of London, and endeavor to satisfy the requirements of the Preliminary Scientific. When, then, an ordinary student is expected to be able to pass in Inorganic Qualitative Analysis, it is easy for him to extend his information by taking in the subjects of the First M.B. The skeleton-notes are suited for students at both these examinations.

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May, 1879.

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* In the Index, all substances printed in *Italics* are those for the First M.B examination of the University of London.

BERNAYS' NOTES

ON

ANALYTICAL CHEMISTRY.

Preliminary.

DISTILLED WATER has no effect upon the color of test-papers. It leaves **no residue** on evaporation, is inodorous and uninflammable. Unaffected by argentum nitrate and by sodium carbonate. Acidulated with hydrochloric acid, no change of color by hydrogen sulphide. If quite pure, no coloration with Nessler's test (absence of ammonia), and no turbidity with lime-water (absence of carbon dioxide).

Nearly all the salts of **potassium, sodium, caesium, rubidium, lithium** and **ammonium** are **soluble** in water.

The CARBONATES, SULPHITES, PHOSPHATES, ARSENATES, ARSENITES, BORATES, TARTRATES, OXALATES, CITRATES, URATES, CHROMATES, SILICATES, of **metals** other than the alkaline metals are more or less **insoluble** in water.

Most metals form hydroxides: those of KALIUM **KOH**, NATRIUM **NaOH**, CAESIUM **CsOH**, RUBIDIUM **RbOH**, LITHIUM **LOH** and AMMONIUM NH_4OH,—of BARIUM $Ba(OH)_2$, STRONTIUM $Sr(OH)_2$ and CALCIUM $Ca(OH)_2$, are **alone soluble in water**. Their solutions turn red litmus paper blue. ARGENTUM NITRATE $AgNO_3$ occasions in them a **grey-brown** precipitate, consisting of ARGENTUM OXIDE Ag_2O, soluble in nitric acid, **and** in ammonia.

E.g. $2KOH + 2AgNO_3 = Ag_2O + H_2O + 2KNO_3$.
$Ba(OH)_2 + 2AgNO_3 = Ag_2O + H_2O + Ba2NO_3$.

Therefore a solution of an hydroxide in water blues red litmus, and is precipitated grey-brown by argentum nitrate: **but**, CARBON DIOXIDE **only precipitates** BARIUM, STRONTIUM and CALCIUM as **carbonates**, inasmuch as the carbonates of potassium, sodium and ammonium are soluble in water.

E.g. $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$.

CO_2 occasions milkiness in solutions of $Ba(OH)_2$, $Sr(OH)_2$ and $Ca(OH)_2$.

A solution of $Ba(OH)_2$, $Sr(OH)_2$, and $Ca(OH)_2$, is of course precipitated by a solution of SODIUM CARBONATE, and thus a separation can be made by precipitation of $BaCO_3$, $SrCO_3$, and $CaCO_3$, from the hydroxides of potassium, sodium and ammonium (lithium, caesium and rubidium also).

N.B. As then the carbonates of the basylous metals, except those of the alkalies, are insoluble in water, a solution of an alkaline carbonate,– say of sodium carbonate Na_2CO_3, occasions a white precipitate of an insoluble carbonate in solutions of metallic salts.

E.g. $BaCl_2 + Na_2CO_3 = BaCO_3 + 2NaCl.$
$FeSO_4 + Na_2CO_3 = FeCO_3 + Na_2SO_4.$

A solution of a salt may be neutral in the chemical acceptation of the word, and may yet redden blue litmus or turn red litmus paper blue. Thus, both CUPRIC SULPHATE $CuSO_4$ and SODIUM CARBONATE Na_2CO_3 are neutral salts, because the hydrogen in both acids H_2SO_4 and H_2CO_3, is replaced by its equivalent of Na_2 and Cu. But Na_2CO_3 blues red litmus, and $CuSO_4$ reddens blue litmus. Sodium carbonate however gives a white precipitate with $AgNO_3$ and therefore they cannot be confounded with an hydroxide (see above).

Thus :—$Na_2CO_3 + 2AgNO_3 = Ag_2CO_3 + 2NaNO_3$.

SODIUM HYDRO-CARBONATE $NaHCO_3$ does not precipitate magnesium salts or solution of tartar emetic ($2[KSbOC_4H_4O_6],H_2O$) until heated. In presence of ammoniacal salts, together with certain metallic salts, such as zinc, magnesium, &c, heat may be necessary, even in using sodium carbonate as a precipitant; but little skill is however required in detecting ammonia *a.* by its smell, *b.* by fumes with hydrochloric acid, and *c.* by blue color to red litmus.

The presence of metallic salts other than of the alkaline metals is then detected by Na_2CO_3, which occasions a precipitate.

If solution reddens test-paper strongly, there will be effervescence on addition of Na_2CO_3: *a.* If effervescence without any precipitate even on boiling, then we have only to deal with a free acid, or an acid salt of alkaline metals. *b.* If effervescence first, with precipitate only becoming permanent on addition of excess of Na_2CO_3, we have a metallic salt together with free acid. *c.* If no effervescence, or effervescence with permanent precipitate, then the reaction on the test-paper is due to the nature of the salt, and there is no free acid.

When a solution is **heated** in a test-tube, the latter should be kept in **continuous agitation**, to prevent ejection of the contents. **Beware** of adding concentrated acids to hot solutions. The **tests** should be employed **gradually**, as otherwise many indications are lost. Whilst **moderation** is suggested in the use of tests, care should be taken to add **sufficient quantities**, as otherwise serious mistakes may arise: thus **excess** must be employed in order to separate members of particular groups. If a liquid is **strongly** acid, dilute before adding most tests. When **filtration** is **required**, do not allow the **washings** to pass into the original liquid. Whenever it is possible to **decant** or pour off the clear liquid from the precipitate, it is easy to wash this way.

TABLE OF THE ELEMENTS, WITH THEIR SYMBOLS AND ATOMIC WEIGHTS, SPECIFIC GRAVITIES AND MELTING-POINTS.

Element.	Symbol.	At. Weights.	Sp. Gravity.	Melting-Point.
Aluminum	Al	27.5	2.67	700°
Argentum	Ag	108	10.468	1000°
Arsenicum	As	75	5.7	
Aurum	Au	196.6	19.265	1102°
Barium	Ba	137	4	
Bismuth	Bi	210	9.823	270°
Boron	B	11	2.68	
Bromine	Br	80	2.966	
Cadmium	Cd	112	8.655	315°
Caesium	Cs	133		
Calcium	Ca	40	1.578	
Carbon	C	12		
Cerium	Ce	141.2	6.728	
Chlorine	Cl	35.5		
Chromium	Cr	52.2	6.81	
Cobalt	Co	58.8	8.95	
Cuprum	Cu	63.4	8.952	1090°
Didymium	D	147	6.544	
Erbium	E	169		
Ferrum	Fe	56	7.79	
Fluorine	F	19		
Gallium	Ga	69.8	5.9	30.1°
Glucinum	G	9.3	2.1	
Hydrargyrum	Hg	200	13.596	−40°
Hydrogenium	H	1		
Iodine	I	127	4.95	107°
Indium	In	113.4	7.42	176°
Iridium	Ir	198	22.40	
Kalium	K	39.1	0.865	62.5°

TABLE OF THE ELEMENTS, ETC.—*continued.*

Element.	Symbol.	At. Weights.	Sp. Gravity.	Melting-Point.
Lanthanum	La	= 139	6.163	
Lithium	L	= 7	0.594	180°
Magnesium	Mg	= 24	1.743	
Manganesium	Mn	= 55	8.013	
Molybdenum	Mo	= 96	8.62	
Natrium	Na	= 23	0.974	95.6°
Nickel	Ni	= 58.8	8.82	
Nitrogen	N	= 14		
Osmium	Os	= 199.2	22.477	
Oxygen	O	= 16		
Palladium	Pd	= 106.5	11.4	
Phosphorus	P	= 31	1.83	44°
Platinum	Pt	= 197.4	21.50	
Plumbum	Pb	= 207	11.367	334°
Rhodium	R	= 104.3	12.1	
Rubidium	Rb	= 85.4	1.516	38.5°
Ruthenium	Ru	= 104.4		
Selenium	Se	= 79.5	4.5	217°
Silicium	Si	= 28	2.49	
Stannum	Sn	= 118	7.294	235°
Stibium	Sb	= 122	6.713	425°
Strontium	Sr	= 87.6	2.540	
Sulphur	S	= 32	2.07	115°
Tantalum	Ta	= 192		
Tellurium	Te	= 129	6.25	326.6°
Thallium	Tl	= 203.6	11.8	294°
Thorium	Th	= 231.5		
Titanium	Ti	= 50		
Tungsten	W	= 184	17.60	
Uranium	U	= 120	18.4	
Vanadium	V	= 51.2		
Yttrium	Y	= 92.5		
Zincum	Zn	= 65.2	6.915	423°
Zirconium	Zr	= 89.5		

WEIGHTS AND MEASURES.

480 grains Troy = 1 oz. Troy.
437·5 „ „ = 1 oz. Avoirdupois.
7000 „ „ = 1 lb. „

	Grains.
The imperial gallon contains of water at 16.33° C.	70,000
The pint ($\frac{1}{8}$ gallon)	8,750
The fluid ounce ($\frac{1}{20}$) pint	437·5

Measures of Weight and Capacity.

	In English grains.		In cubic inches.
Milligram	0.015432	Millilitre	0.061027
Centigram	0.154323	Centilitre	0.610271
Decigram	1.543235	Decilitre	6.102705
Gramme	15.432349	**Litre**	61.027052

Appearances of the more commonly occurring Bodies :—

Metallic lustre more or less marked. The metals, graphite, iodine, many metallic sulphides and arsenides as ores (lead, silver, copper, iron, tin, antimony, bismuth, nickel, cobalt; ferric, ferroso-ferric, and stannic oxides as ores, manganese peroxide (pyrolusite, crystallized), anhydrous ferric chloride.

Black. Most of the above in a finely divided state; the precipitated sulphides of lead, iron, bismuth (brownish), mercury, gold, platinum, silver, cobalt and nickel; manganese, nickel, and cobalt peroxides; reduced iron, lead, and platinum: ferrous, ferroso-ferric, stannous, mercurous, and cupric oxides; lead suboxide, cupric and other phosphides, ferric tannate and ferrous gallate (ink).

White or colorless. Salts of the following, unless the acid radicle be colored :—alkalies and alkaline earths, zinc, tin, aluminum, bismuth, antimony, cadmium, silver, mercury (neutral salts), lead, and copper in the euprous form. Alkaloids, sugars, starches, glycerine, alcohol, urea; if pure. Distilled water. Free acid radicles or hydrogen salts, except chlorine, bromine, iodine, and sulphur, chromic, bismuthic, hypochlorous and nitrous acids. Oxides and hydroxides of alkalies, alkaline earths, zinc and aluminum; plumbic and cadmic hydroxides; ferrous and manganous hydroxides (rapidly changing); ferric phosphate; most ferrous salts when anhydrous.

Yellow. Ferric salts (acid), most neutral chromates, basic salts of mercury, silver orthophosphate and arsenite; sulphur, soluble persulphides, cadmic, arsenious, and stannic sulphides; plumbic oxide ("massicot"), oxychloride ("Turner's yellow"), and iodide; mercuric oxide (precipitated), cuprous hydrate, zinc oxide when heated; potassio-cobaltous nitrite ("aurcolin");

bromide of starch; cadmium, nickel, mercuric and bismuth ferricyanides; auric oxide and chloride, ammonio- and potassio-platinic chlorides.

Pale or Light yellow. Hypochlorous acid, chlorine water and gas, silver iodide, precipitated sulphur, lead antimoniate ("Naples yellow"), ferrous oxalate, antimonic anhydride, tannic acid, potassium ferrocyanide ("honey yellow"), mercuric chlorosulphide (changing from white to yellow, orange, red, brown, black).

Green. Cupric chloride, hydrocarbonate (malachite), basic acetate (also blue-"verdigris"), ferricyanide, arsenite (Scheele's green), aceto-arsenite (emerald green); nickelous hydroxide, most ferrous and nickel salts; chromic oxide, hydroxide, and salts (also violet); aurous, nickelous and manganous oxides (dark olive); zinc cobaltate ("Rinman's green," blowpipe test), cobalt ferrocyanide (dirty green to grey) mercurous iodide (yellowish), manganates (intense bluish green, blowpipe test), nitrous acid (varies), potassium ferrocyanide solution (yellowish).

Blue. Cupric hydrate, hydrocarbonate (Chessylite), nitrate, sulphate, acetate, arsenate, &c.; basic and anhydrous cobalt salts, cobalt glass ("smalt"), cobalt aluminate ("Thenard's blue," blowpipe test), ultramarine, solution of nickelous hydroxide in ammonia.

Dark blue. Cupric salts with excess of ammonia, Fehling's test, Prussian blue, iodide of starch.

Violet or Purple. Chromic salts (also green), some cobalt compounds, purple of Cassius (auric stannate); ferrates and perchromic acid (unstable); murexide (uric acid test), solution of I in CS_2 or $CHCl_3$, iodine vapor.

Crimson. Permanganates, argentic chromate.

Pink or flesh-colored. Manganous sulphide, chloride, sulphate, &c.; cobaltous hydroxide and many salts in solution; magnesium cobaltate (blowpipe test).

Orange. Nitric acid containing nitrous, bromine water, antimonous sulphide, some chromates and ferric salts, zinc and argentic ferricyanide, auric chloride (dry), nitrogen peroxide, bromine vapor.

Brick-red. Plumbic oxide (litharge) and chlorosulphide, arsenic and phosphorus iodides, realgar (As_2S_2), mercurous chromate.

Orange-red. Acid chromates, some ferric compounds, mercuric chromate (yellow at first).

Red. Basic lead chromate, red lead, cinnabar and vermilion (mercuric sulphide), cuprous oxide, chromic anhydride, mercuric oxide ("red precipitate"), and iodide.

Rose-red. Cobalt salts.

Brown-red. Ferric oxide, mercuric oxychloride ($NaHCO_3$+

$HgCl_2$), amorphous phosphorus, solid potassium ferricyanide, sodium nitroprusside, manganic salts (unstable), reduced copper, ferric acetate, formate, meconate, and sulphocyanide, bromine, chlorochromic acid CrO_2Cl_2, cupric ferrocyanide (maroon).

Brown. Reduced gold, ferric hydroxide (varies), plumbic peroxide, ferric succinate and urate (reddish), ferric benzoate (pale), blende (ZnS), cadmium oxide, bismuth iodide and bismuthic acid, stannous sulphide, silver arsenate, iodine water (light), iodine tincture and alkaline triiodides (deep), platinic chloride and other compounds, neutral ferric solutions, some oxides of chromium, uranium ferrocyanide (dark), manganous ferricyanide, cobalt ferricyanide (purple-brown), mercurammonium iodide (Nessler precipitate), cupric chromate (orange-brown), solution of cobalt hydroxide in ammonia (becomes red), sulphur vapor, plastic sulphur.

Grey. Precipitated antimony, arsenic, mercury and silver, silver oxide (brown-grey), cobaltous oxide, silver antimonide, anhydrous cupric sulphate.

[Many organic substances may be brown, yellowish or grey from impurity.]

USUAL APPEARANCES OF CRYSTALS:—

Transparent needles. Oxalic acid (also thicker and more opaque), magnesium, zinc, sodium, ammonium and quina sulphates, calcium chloride (deliquescent) urea, calcium sulphate (rather rare), ammonium nitrate, chloride and oxalate, gallic acid (minute), sodium acetate, cupric chloride, hydrated ferric chloride (brown, deliquescent), soluble succinates, potassium picrate (yellow), urea oxalate, [thein, and many alkaloids].

Opaque needles. Hippuric acid, morphia, strychnia, magnesium phosphate (minute), stannous chloride, lead acetate, mercuric and lead chlorides, potassium permanganate (dark purple), calcium benzoate, prismatic sulphur, potassium nitrate.

Pearly or resinous lustre: (*a*) **needles**; silver acetate, aluminium sulphate, potassium ferricyanide.

(*b*) **plates or scales**; benzoic acid and soluble benzoates, barium chloride, boracic acid, urea nitrate, potassium ferrocyanide (also massive square tables), barium hydrate, cadmium and lead iodides, chromic chloride (anhydrous, violet), potassium chlorate (?), [croton chloral, santonine, leucine, picric acid (also octahedra), some fatty acids, cholesterine, sebacic acid.] mercurous acetate.

Short, thick crystals: (*a*) **efflorescent**; most sodium salts, alums (octahedra), tartar emetic, cupric and ferrous sulphates, lead acetate, mercurous nitrate.

(*b*) **deliquescent**; malic, phosphorous and phosphoric acids, zinc acetate, cadmium nitrate, hydropotassic sulphate.

(*c*) **permanent**; potassium chromate, dichromate, hydro-carbonate, sulphate, binoxalate, &c., tartaric and citric acids (if pure), strontium nitrate, cale-spar ($CaCO_3$), Rochelle salt (sodio-potassic tartrate), sucrose, gypsum, &c.

(*d*) **opaque**; plumbic nitrate (very marked), succinic acid, lactose, potassium hydrogen tartrate, mercuric cyanide, cinchonine salts.

Cubes. Chlorides, bromides and iodides of alkaline metals (cyanides usually in mass), iron pyrites FeS_2, galena PbS, fluor-spar CaF_2. Potassium bromide is usually more transparent than the iodide.

Substances commonly met with in masses, cakes, or lumps: fused salts generally, especially the following:—

Structure pearly flakes: pure sodium and potassium hydroxides, potassium and sodium acetates. **Fibrous**; ammonium chloride. **Granular crystalline**: aluminum sulphate, mercuric chloride, potassium disulphate, fused calcium chloride, glucose, camphor, silver nitrate (sticks), potassium nitrate ("sal prunella," sticks or balls, "glob. prunel."), roll sulphur. These may also appear:

Amorphous: (*a*) **opaque**; arsenious anhydride (porcellanous, stratified), common caustic potash and soda (sticks or cakes), fused antimonious sulphide (dark brown), potassium cyanide and nitrite, manganates (dark green), silicates, zinc chloride (deliquescent sticks), barium oxide.

(*b*) **transparent**; glacial phosphoric acid (deliquescent sticks or lumps), quartz and mixed silicates (glass), phosphorus (waxy, becomes opaque white, yellow, orange, red), sucrose in the form of barley sugar [gelatine, soluble albumen, gums, resins, &c.].

Gelatinous or flocculent bodies (Colloids). Hydric and many other silicates, most precipitates from solutions of aluminum, iron, chromium, manganese, nickel, and cobalt salts, potassium and barium silicofluorides, calcium fluoride, gelatine, albumen, starch when boiled, &c. Many precipitates at first floccular become granular or even crystalline by heat or standing.

Crystalline precipitates. Potassium and ammonium hydro-tartrates, benzoic, hippuric, boracic, arsenious, chromic, uric, gallic, salicylic and picric acids, ammonio- and potassio-platinic chlorides, magnesium and ammonio-magnesium phosphates (minute), plumbic chloride, bromide, iodide, and sulphocyanide, cuprous chloride, barium chloride and nitrate (by strong acids), silver acetate, potassic perchlorate, urea nitrate and oxalate.

Syrupy liquids. Concentrated solutions of very soluble bodies, such as potassium and sodium hydroxides, potassium carbonate, zinc and ferric chlorides, tartaric, malic and citric

acids, sucrose, &c.; glycerine; phosphoric, arsenic, sulphuric and lactic acids [gum, albumen, gelatine, &c.].

The above list embraces the substances most frequently met with, including a few characteristic ones out of the range of ordinary analysis, and omitting the majority of bodies enumerated in the table of colors.

The **amorphous powders** are too numerous to specify. Opaque dead-looking powders are usually insoluble in water. If colored, a heavy metal is generally present. "Scale preparations," such as citrates and tartrates of iron, simulate crystals, but are irregular in form. Substances may be colored yellowish, brownish, &c., by impurity; this is frequently the case with glucose, tannin, alkaloids, malic, uric and meconic acids. Pulverization generally diminishes color in proportion to the fineness of the division; sometimes the tint is removed or entirely changed. As a rule, colored bodies, if soluble in water, give solutions of the same or similar hue, ferro- and ferricyanides being notable exceptions. Lead and mercuric iodides give colorless solutions, so also do many other bodies in dissolving in acids. The deep blue tint of ammonio-cupric solutions is removed by potassium cyanide. The color of precipitates often varies with different circumstances of precipitation.

Fluorescent bodies. Quina salts in solution [chlorophyll, æsculin, eosin, "paraffin oil," uranium compounds].

Substances more or less dichroic. Some salts of chromic oxide, potassium ferricyanide, platino-cyanides, nickel hydroxide in ammonia, [most aniline dyes, indigo,] Prussian blue, potassium permanganate crystals.

Characteristic odors. Cl, Br, I, SO_2, H_2S, [H_2Se, H_2Te], HCl, HBr, HI, HCN, $(CN)_2$, HF, NO_2, NH_3; PH_3 (stinking fish), As and AsH_3 (garlic); Cl_2O (from hypochlorites); acetic, formic, and benzoic acids; burnt sugar (sugars and tartaric acid on heating); burnt feathers (protein compounds by heat); pleasant ethereal (acetic and formic ethers, from acetates and formates, by heating with alcohol and H_2SO_4); aldehyd (from alcohol by $K_2Cr_2O_7$ and H_2SO_4); alcohol (nearly inodorous when pure), [ether, chloroform, CS_2 and a large number of organic compounds]; acrolein (intensely pungent, from glycerin by $KHSO_4$ and heat); pungent odor from oxalic, benzoic, citric and succinic acids by heat.

Preparatory Experiments.

Carefully note appearances: if a solid, is it metallic, colored, white or colorless (p. 5); crystalline (p. 7) or amorphous?

HEAT IN SMALL GLASS-TUBE. *a.* **volatilize readily**: salts of NH_4 with volatile radicles,—of Hg or Hg_2,—As_2O_3 or As_2O_5,—certain chlorides as of Sn, Sb, &c.,—certain organic bodies,—water of crystallization, &c. *b.* **fuse without blackening**: hydroxides of K, Na, Ba,—salts of alkalies and alkaline earths,—boracic, phosphorous and phosphoric acids, &c. *c.* **evolve nitrous fumes**, nitrates and nitrites. *d.* evolves Cyanogen, kindling with peachblossom-colored flame,—cyanides of Ag, Hg. *e.* **give off brown vapors**, burning with odor of sulphur dioxide,—sulphur and certain sulphides. *f.* **blacken or char**,—certain organic bodies,—various salts with metallic bases. Those of the alkaline metals K and Na leave a residue of a carbonate, alkaline to test-paper, and soluble with effervescence in HCl. *g.* **undergo no change**,—silica, barium, strontium, and calcium sulphates.

ASCERTAIN IF SUBSTANCE IS SOLUBLE IN WATER.

Place a few grains in a test-tube, and add a little distilled water; shake and heat carefully. If **soluble**, note whether solution colorless or colored.

I. THE SUBSTANCE IS SOLUBLE IN WATER.

1. USE RED LITMUS PAPER: it is turned **blue**. *a.* Add SODIUM CARBONATE: no reaction even after stirring and heating (if required); it is either **potassium** or **sodium hydroxide** or a **salt** of **K** or **Na** with alkaline reaction. To a fresh portion add SILVER NITRATE: the precipitate is **greyish-brown**, soluble in NH_3 and in HNO_3; it is **KOH** or **NaOH**. The precipitate is **liver-brown**, soluble in NH_3 and in HNO_3, it is an **alkaline arsenate**. The precipitate is **yellow**, soluble in NH_3 and in HNO_3, it is an **alkaline arsenite** or **phosphate**. **Yellow**, and insoluble, an **iodide**. The precipitate is white, and easily soluble in HNO_3 and in NH_3,—an **alkaline borate, sulphite, carbonate, tartrate, oxalate, acetate, benzoate, citrate, hippurate** or **succinate**. The precipitate is white and curd-like, with difficulty soluble in NH_3 and only soluble in boiling HNO_3,—an **alkaline cyanide**. The precipitate is white, yellow, orange and, by heat, **black**,—an **alkaline hyposulphite**. The precipitate is **black**,—an **alkaline sulphide**.

N.B. Many other salts of K, Na, and NH_4 are precipitated by $AgNO_3$, but they are either neutral, or acid, to test-paper. Salts of ammonium would be recognized by Na_2CO_3, as ammonium carbonates are volatile, odorous of NH_3, which turns red litmus blue, and fumes with glass-rod dipped in HCl.

1. **Examine the solution with test-papers.** LITMUS PAPER

BLUED. β. add **sodium carbonate**: an immediate **white precipitate**. To a fresh portion add **silver nitrate**,—a **grey-brown** precipitate, soluble in HNO_3, and in HNO_3, it is a **hydroxide** of **barium, strontium** or **calcium**.

2. **Examine the solution with test-paper.** BLUE LITMUS IS REDDENED. γ. Add solution of **sodium carbonate** Na_2CO_3. EFFERVESCENCE **without** any **precipitation** or turbidity,—either a free acid is present, or an acid salt of K, Na or NH_4. EFFERVESCENCE, **with** permanent turbidity or **precipitate**, and with resolution until free acid is neutralized,—free acid together with soluble salt of alkaline earth, earthy or any heavy metal. No EFFERVESCENCE, but **precipitate at once**: then the reddening of the litmus is due only to the nature of the metallic salt, as many salts have an acid reaction. No EFFERVESCENCE, and only a precipitate after long stirring,—probably a salt of quina, cinchona, morphia or strychnia. No EFFERVESCENCE, and a precipitate on heating,—tartar emetic. No EFFERVESCENCE, and no precipitate,—possibly mercuric cyanide.

3. **Examine with test-papers, red and blue:** NO CHANGE OF COLOR. δ. Add solution of **sodium carbonate**. No PRECIPITATE, even on boiling: absence of all salts, except of K, Na and NH_4. A PRECIPITATE: presence of any neutral metallic salts, as of Ba, Sr, Ca, &c.

It should be noticed that **sodium hydro-carbonate** $NaHCO_3$ only precipitates salts of magnesium and tartar emetic when heated, or on long standing, and does not precipitate mercuric cyanide.

In further testing for the metals, the latter are divided into 6 groups, according to precipitation, or otherwise.

GROUP I. **By HCl** precipitated as CHLORIDES: lead, silver and mercurous. $PbCl_2$, $AgCl$ and Hg_2Cl_2.

GROUP II. **By HCl + H_2S**, precipitated as **sulphides**. *a.* SULPHIDES soluble in $(NH_4)_2S_2$; arsenicum, antimony, stannous and stannic (gold and platinum), As_2S_3, Sb_2S_3, SnS_2, Au_2S_3 and PtS_2. *b.* SULPHIDES, insoluble in $(NH_4)_2S_2$: lead, mercuric, bismuth, copper and cadmium, **PbS**, **HgS**, Bi_2S_3, **CuS**, **CdS**. [A ferric salt is reduced in acid solutions, by H_2S, into a ferrous salt, and a salt of **chromic acid** into a salt of chromic oxide, with deposit of **yellow** sulphur. A similar deposit occurs in solutions of chlorine, bromine, iodine and HNO_3. Arsenates only precipitated, after long boiling, and by large excess.]

GROUP III. By NH_4OH, after addition of NH_4Cl to original solution, the hydroxides of ferric, chromic and aluminic $Fe_2(OH)_6$, $Cr_2(OH)_6$ and $Al_2(OH)_6$ are precipitated.

GROUP IV. By $(NH_4)_2S$ in presence of NH_4Cl, as sulphides, zinc, manganous, ferrous, cobalt and nickel, ZnS, MnS, FeS, CoS, NiS.

GROUP V. By $(NH_4)_2CO_3$, in presence of NH_4Cl, as carbonates, barium, strontium and calcium, $BaCO_3$, $SrCO_3$, $CaCO_3$.

As already stated, Na_2CO_3 precipitates all these metals, with the exception of those which have acid characters, such as As_2O_5, As_2O_3 and CrO_3. So then magnesium would be precipitated, and if no other reaction answers, it is a salt of Mg.

GROUP VI. No reaction. K, Na, (Cs, Rb, L), or NH_4. This group is determined by the Na_2CO_3 test, which also discovers the presence or otherwise of NH_4. If not a salt of NH_4, add $HCl + PtCl_4$: a yellow precipitate, $2KCl,PtCl_4$; if none, Na.

The colors communicated to flame are very helpful, but as a rule it is better not to heat upon platinum-foil until we have ascertained something of the character of the unknown compound by means of test-papers, Na_2CO_3 and $AgNO_3$. Salts of K, violet. Na, yellow. If K and Na together, look through blue glass, which absorbs the yellow rays. L, purple-crimson. Sr, crimson. Ca, yellow-red. Cu, green or blue. Tl, green. Ba, yellowish-green. B_2O_3, green. P, green. As, bluish. Sb, greenish-white.

II. THE SUBSTANCE IS INSOLUBLE IN WATER (see p. 41).

ANALYSIS OF AQUEOUS SOLUTIONS, CONTAINING ONE HYDROXIDE, OR ONE ACID, OR ONE RADICLE OR A SIMPLE SALT.

Tests for bases in soluble salts.

a. Look to color. *b*. Whether neutral, alkaline or acid to litmus paper. *c*. Add Na_2CO_3; a white precipitate, therefore a heavy metal is present. [A salt of quina, cinchona, morphia or strychnia would also be precipitated. *First M.B. examination at University of London*, see pp. 43–51.]

Group I. Hydrochloric acid* precipitates the chlorides of lead

* HCl will also precipitate basic antimonous chloride, soluble in excess, from solutions of tartar emetic; cream of tartar from potassium tartrate; arsenious acid from soluble arsenites, and the respective acids from alkaline borates, silicates, titanates, antimonates, stannates, molybdates, tungstates;

$PbCl_2$, (thallium TlCl), mercurous Hg_2Cl_2 and silver AgCl. Their sulphides are black or brown-black and insoluble in $(NH_4)_2S_2$.

1. **Lead oxide PbO, yellow.** Hydroxide $Pb(OH)_2$, white and soluble in KOH. [Chief soluble salts: acetate, nitrate and chloride. Neutral or feebly acid to test-paper. Goulard's extract, alkaline.] **HCl** as white $PbCl_2$, soluble in HCl in excess, and in much water: **not in NH_3** and **unchanged white.** **H_2S black** sulphide, **PbS.** In solutions of $PbCl_2$ in HCl, H_2S gives **red** precipitate of lead **chloro-sulphide** $2PbCl_2, 3PbS$, turning to **black PbS** when H_2S in excess. **Na_2CO_3**, already used: precipitate of white lead $Pb(OH)_2, 2PbCO_3$. **KOH**, white hydroxide soluble in excess. **NH_4OH** white hydroxide, either at once or on heating. **H_2SO_4** white **lead sulphate** $PbSO_4$, soluble in ammonium acetate. **$K_2Cr_2O_7$**, yellow lead chromate **$PbCrO_4$**, soluble in KOH. **KI yellow PbI_2**, soluble in much boiling water. Potassium ferrocyanide K_4FeCy_6, white lead ferrocyanide Pb_2FeCy_6. Lead easily precipitated by Zinc. Before blowpipe on **charcoal**, bluish lustrous bead, malleable: incrustation of **yellow oxide.** Pb is estimated as $PbSO_4$ with 68.32 per cent. of metal. Lead must be sought for in Group II., as lead chloride is soluble in much water.

[2. **Thallium oxide** Tl_2O, in hydrated **pale-yellow** prisms, very soluble in water, and with alkaline reaction **TlOH.** HCl yellowish-white TlCl, little soluble in HCl. H_2S scarcely a reaction, but NH_4HS **brown-black sulphide TlS.** **Na_2CO_3**, white precipitate in concentrated solutions. **H_2SO_4** no reaction. **K_2CrO_4 pale-yellow** precipitate **Tl_2CrO_4.** **KI reddish-yellow** TlI. **$PtCl_4$** little soluble $2TlCl, PtCl_4$. Metallic zinc precipitates **Tl.** Salts give **green** color to flame. Reduced upon **charcoal.**]

3. **Mercurous oxide Hg_2O, black.** (Chief salt nitrate; strongly acid. Mercurous chloride or calomel is insoluble in water, sublimes when heated, blackened by NH_3 forming NH_2Hg_2Cl, and soluble as mercuric chloride in aqua regia.) **HCl** whitish **Hg_2Cl_2**, insoluble in water, and into **black NH_2Hg_2Cl** by **NH_3**; easily oxydized by HNO_3 into $HgCl_2$ and Hg_2NO_3, with evolution of nitrous fumes. **H_2S black Hg_2S**, soluble in aqua regia as mercuric chloride, (and then precipitated yellow, orange, black, by H_2S.) **Na_2CO_3 black** precipitate of **Hg_2O.** **KOH black Hg_2O.** **NH_3 black Hg_2O.** **$K_2Cr_2O_7$ brick-dust colored**

aluminum and zinc hydroxides from solutions in alkalies; sulphur from the higher sulphides of alkalies and alkaline earths; sulphur with evolution of sulphur dioxide from hyposulphites; uric acid, hippuric acid, benzoic acid, and gallic acids from alkaline salts. HCl will immediately remove CO_2 from carbonates; HNO_2 from nitrites; HCN from cyanides, &c., &c.

Hg_2CrO_4. **KI** yellow-green Hg_2I_2. K_4FeCy_6 white mercurous ferrocyanide. $SnCl_2$ first a precipitate of mercurous chloride and then of grey mercury. Thus: $Hg_2Cl_2+SnCl_2=Hg_2+SnCl_4$. Copper, zinc and iron, precipitate **Hg**. **Mercury is usually estimated as Hg.** Salts reduced in tube with Na_2CO_3. Heated on platinum, Hg_2NO_3 first white, yellow, red, black, and then volatilized.

4. **Argentum oxide Ag_2O grey-brown, soluble in NH_3.** (Chief salts: nitrate and sulphate. Neutral to test-paper.) **HCl** white, curd-like **AgCl**, insoluble in water, (soluble in concentrated HCl, in solution of NaCl, &c., but re-precipitated on addition of water,) **soluble in NH_3**, and changing in color from white to violet on exposure to light. **H_2S brown-black Ag_2S**, soluble in boiling HNO_3. **Na_2CO_3** white Ag_2CO_3, soluble in NH_3 and salts. **KOH grey-brown Ag_2O**, soluble in NH_3 and in HNO_3. **NH_3**, like KOH, but precipitate so soluble, that, in presence of free acid, there is no precipitate. **$K_2Cr_2O_7$ crimson Ag_2CrO_4. KI yellow AgI**, insoluble in NH_3 and in HNO_3: iodide thus distinguished from a chloride. POTASSIUM CYANIDE KCN white, curd-like AgCN, soluble in excess of precipitant. Cu, Fe, Hg, Zn, precipitate **Ag**. On **charcoal**, with Na_2CO_3, or alone, reduced to white, lustrous bead, without incrustation: malleable. **Silver** is weighed as **chloride**, containing 75.26 per cent. of **silver**, or as **silver**.

GROUP II. **HCl + H_2S precipitates**: A. **as sulphides soluble in $(NH_4)_2S_2$**, yellow As_2S_3 and pale-yellow SnS_2; orange Sb_2S_3; brown **SnS**; black Au_2S_3 and PtS_2: B. **as sulphides, insoluble in $(NH_4)_2S_2$**, yellow **CdS**; deep-brown Bi_2S_3; blue-black **PbS**; brown-black **CuS**; black **HgS** and **PdS**.

N.B.—A FERRIC SALT is reduced to a FERROUS, and a salt of CHROMIC ACID to one of CHROMIC OXIDE by H_2S.

A. Sulphides soluble in $(NH_4)_2S_2$.

Arsenicum as arsenious anhydride As_2O_3, or as a soluble **arsenite** (DI-POTASSIUM HYDROGEN ARSENITE K_2HAsO_3, the common salt: strongly alkaline, colorless. no reaction with Na_2CO_3, and **yellow** precipitate with $AgNO_3$, soluble in HNO_3 and in NH_3). IN ALKALINE ARSENITES. **HCl**, in concentrated solutions, a white precipitate of As_2O_3, soluble in excess. **HCl + H_2S, bright-yellow As_2S_3**, soluble in NH_3, in **$(NH_4)_2CO_3$** and in $(NH_4)_2S_2$. **$CuSO_4$, green $CuHAsO_3$**, soluble in NH_3. **$AgNO_3$, yellow Ag_3AsO_3**, soluble in NH_3 and in HNO_3. **$BaCl_2$**, white $BaHAsO_3$, soluble in HCl. IN SOLUTIONS OF ARSENIOUS ACID. Litmus is reddened, yet

no visible reaction with Na_2CO_3. **$CuSO_4$** no reaction until NH_3 carefully added, so as to form an arsenite: then "Scheele's Green" $CuHAsO_3$. **$AgNO_3$**, no reaction until NH_3 carefully added. **Reinsch's test: Cu** and HCl added to solution:—a steel-grey deposit of copper arsenide: the metal withdrawn, washed, dried in water-bath, heated in glass-tube: As_2O_3 sublimes in octohedra. **Marsh's test: Mg** or **Zn** in presence of H_2SO_4, yields **AsH_3**, burning with bluish-white flame to H_2O and As_2O_3: if incompletely burnt, **As** is deposited. soluble in $CaOCl_2$. Also filter-paper moistened with $AgNO_3$ may be suspended in tube where AsH_3 is evolved; **Ag** is deposited. Avoid HNO_3, as solid hydride may be formed. **On charcoal,** mixed with Na_2CO_3, garlic odor, and bluish-white flame. Heated in tube with black flux **As** volatilizes: $2As_2S_3 + 6K_2CO_3 + 6C = 6K_2S + 6CO + 6CO_2 + As_4$.

Arsenicum, as **arsenic acid H_3AsO_4.** In solutions of **arsenates** (the **alkaline** are **alone soluble** and colorless: chief soluble salt $Na_2HAsO_4,12H_2O$), **$HCl + H_2S$** occasions no immediate precipitate: **but** if excess of H_2S be added, and about 20 drops reduced, by boiling, to three, the further addition of H_2S gives an **immediate yellow** precipitate of **$As_2S_3 + S_2$.** **$AgNO_3$ liver-brown** precipitate, both in H_3AsO_4 and in arsenates, soluble in NH_3 and in HNO_3: **$CuSO_4$**, no precipitate in H_3AsO_4, but a pale **greenish-blue** pr. of $CuHAsO_4$ in alkaline arsenates. **$MgSO_4$** in presence of NH_3 and a salt of NH_4, a white crystalline precipitate of **$MgNH_4AsO_4,6H_2O$,** isomorphous with $MgNH_4PO_4,6H_2O$. **$BaCl_2$** in arsenates, a white precipitate of $BaHAsO_4$, soluble in HCl. For other tests, see **As_2O_3.**

5. **Stannic oxide SnO_2, brown.** HYDROXIDE $SnO(OH)_2$. Chief salts: STANNIC CHLORIDE **$SnCl_4$** and SODIUM STANNATE **$Na_2SnO_3, 3H_2O$.** Solution of $SnCl_4$, colorless, strongly acid: effervesces first with Na_2CO_3, and then permanent gelatinous hydroxide. **$HCl + H_2S$** dirty **yellow SnS_2,H_2O,** soluble in $(NH_4)_2S_2$ and in KOH. **KOH** white hydroxide, soluble. **NH_4OH,** white. **Zn** precipitates **Sn.** **On charcoal** with Na_2CO_3, a globule of lustrous tin, malleable, and with white incrustation. **Tin** is weighed as SnO_2 containing 78.66 per cent. of metal.

6. **Antimonous oxide Sb_2O_3,** white. HYDROXIDE, white. Chief salts: ANTIMONOUS CHLORIDE $SbCl_3$ strongly acid, and TARTAR EMETIC $2(KSbOC_4H_4O_6)H_2O$ faintly acid. On addition of Na_2CO_3 to $SbCl_3$, a white precipitate of hydroxide, with effervescence: with tartar emetic scarcely any till warmed. Water alone precipitates $SbCl_3$, as **$SbOCl + 2HCl$**, soluble in TARTARIC ACID $C_2H_2(OH)_2(COOH)_2$, and precipitated as **orange**

sulphide by H_2S. **HCl** in sols. of tartar emetic a white prec. soluble in excess. **HCl + H_2S orange Sb_2S_3**, soluble in $(NH_4)_2S_2$, in KOH **and in HCl. KOH** white Sb_2O_3, soluble. **NH_4OH,** white Sb_2O_3: only by heat in tartar emetic. REINSCH'S TEST: **Cu** covered with **violet-grey** deposit of Sb: by strong heat in tube, Sb_2O_3 volatilized in needles. Or, the deposit heated with KOH, exposing the metal freely to the air, gradually oxydized and dissolved: then diluting, passing H_2S, filtering from CuS and adding H_2S, when **orange** Sb_2S_3 thrown down. MARSH'S TEST: **Sb** soluble in $(NH_4)_2S_2$, and separating, on evaporation, as Sb_2S_3. **Or,** SbH_3 from Marsh's test, against paper soaked in $AgNO_3$, yields **black $SbAg_3$. Zn** in presence of HCl precipitates Sb in platinum-dish as black powder on the Pt. **Sn** precipitates **Sb.** Sb_2S_3 is separated from As_2S_3 by $(NH_4)_2CO_3$. **Antimony** is **weighed** as **Sb_2O_4**, containing 79.22 per cent. of metal. Separated from Pb, Cu, Bi, Ag and Fe by K_2S_2, in which Sb_2S_3 is soluble.

7. **Stannous oxide SnO black**; HYDROXIDE $2SnO,H_2O$ white. Chief salt STANNOUS CHLORIDE $SnCl_2,2H_2O$, colorless, strongly acid, effervesces with Na_2CO_3 which throws down the hydroxide. Solution, when not too much free acid, decomposed by water into white OXYCHLORIDE **$SnO,SnCl_2,2H_2O$. HCl+H_2S, light brown** hydrated sulphide **SnS,H_2O,** soluble by heat as STANNIC SULPHIDE SnS_2 in $(NH_4)_2S_2$ and re-precipitated as **yellow** SnS_2 on addition of HCl. Stannous sulphide is soluble in boiling HCl. **KOH** white hydroxide, soluble in excess. Boiled with insufficient potassium hydroxide to dissolve $2SnO,H_2O$, **black** crystalline needles of **SnO** obtained. **NH_4OH,** white hydroxide. **$HgCl_2$,** first precipitates white Hg_2Cl_2, and, in excess, grey metallic mercury: $SnCl_2+2HgCl_2=SnCl_4+$**Hg_2Cl_2**. Then $SnCl_2+Hg_2Cl_2=SnCl_4+$**Hg_2**. AURIC CHLORIDE **$AuCl_3$** in presence of a little $SnCl_4$ as well as $SnCl_2$, produces **Purple** of Cassius. On CHARCOAL, with Na_2CO_3, a white lustrous bead of tin, with incrustation of SnO_2. Tin is weighed as **SnO_2**, containing 78.66 per cent. of metal. When tin and antimony together, their chlorides decomposed by Zinc, the two metals washed, dried and weighed, re-dissolved in weak aqua regia, and the antimony removed by metallic tin.

[8. **Auric oxide Au_2O_3, brown**; HYDROXIDE **$Au_2H_6O_6$, is yellow.** Chief salt AURIC CHLORIDE $AuCl_3$, **dark-red,** deliquescent, or **yellow-red.** Strongly acid to test-paper: **colored. HCl + H_2S, black Au_2S,Au_2S_3,** soluble in $(NH_4)_2S_2$. **KOH yellow-brown** AURATE $KAuO_2,3H_2O$, soluble. **NH_4OH, olive-brown,** fulminating nitride. **$SnCl_2$,** containing a little $SnCl_4$, yields **Purple of Cassius** $SnAu_2Sn_2O_6,4H_2O$. Metallic tin gives similar precipitate. **Oxalic acid** reduces Au_2Cl_3 to metallic gold: $2AuCl_3+3H_2C_2O_4=6HCl+6CO_2+2$**Au**, as a **brown** powder, malleable,

lustrous, golden when flattened in mortar. $FeSO_4$, also reduces Auric chloride: $6FeSO_4 + 2AuCl_3 = Fe_2Cl_6 + 2(Fe_23SO_4) + 2Au$. Hg_22NO_3 also precipitates gold. Gold is weighed as gold.]

[9. Platinic oxide PtO_2, blackish-brown; HYDROXIDE reddish-brown. Chief salt: PLATINIC CHLORIDE $PtCl_4$, reddish-brown or reddish-yellow, acid to test-paper. $HCl + H_2S$, brown PtS_2, immediately on heating, only soluble in aqua regia, and in large excess of $(NH_4)_2S_2$. NH_4Cl and KCl (CsCl and RbCl) produce respectively yellow precipitates of $2NH_4Cl,PtCl_4$ and $2KCl,PtCl_4$ ($2CsCl,PtCl_4$ and $2RbCl,PtCl_4$). By these reactions, Pt easily recognized. When heated, Pt remains as an infusible grey powder, flattened under pestle in mortar into lustrous metal. $SnCl_2$ reduces $PtCl_4$ to dark-brown $PtCl_2$. On charcoal, reduced to grey powder, soluble with reddish-brown color in aqua regia. Platinum is weighed either as metal; as $2KCl,PtCl_4$, containing 40.36 per cent., or as $2NH_4Cl,PtCl_4$ containing 44.18 per cent. of Pt.]

Group II. B. *continued.* $HCl + H_2S$ precipitates Cadmium sulphide CdS, yellow; Bismuth sulphide Bi_2S_3, deep-brown; Lead sulphide PbS, blue-black; Cupric sulphide CuS, Mercuric sulphide HgS, and Palladium sulphide PdS, black. Also a deposit of Sulphur (yellow or white) from ferric salts which are yellow, yellow-red or red-brown, and from salts of chromic acid which are yellow or yellow-red.—The sulphides are insoluble in ammonium disulphide or sulphide. Cd. Bi. Pb. Cu. Hg. Pd.

10. Cadmium oxide CdO, brown. HYDROXIDE Cd $(OH)_2$ white, soluble in NH_4OH. Soluble salts colorless, faintly or distinctly acid to test-paper. Chief salts: $Cd2NO_3$. $CdSO_4, 4H_2O$. $CdCl_2, 2H_2O$. CdI_2. $CdBr_2$. Na_2CO_3, white $CdCO_3$. $HCl + H_2S$ light yellow CdS, soluble in HNO_3 and hot dilute $H_2SO_4.2H_2O$. KOH, white $Cd(OH)_2$. NH_4OH white $Cd(OH)_2$, so soluble in excess, that no prec. if free acid present. $(NH_4)_2CO_3$ white $CdCO_3$, soluble in KCN. K_4FeCy_6, yellowish-white Cd_2FeCy_6. K_6Fecy yellow-brown. On charcoal, in reducing flame, brownish incrustation of CdO. Cadmium is weighed as CdO containing 87.5 per cent. of metal.

11. Bismuth oxide Bi_2O_3, yellow, fusible at red-heat. HYDROXIDE, white. Chief soluble salts: $Bi3NO_3,5H_2O$; $BiCl_3$; colorless, strongly acid. Water alone decomposes them, respectively, into $Bi_2O_3,Bi3NO_3,3H_2O$ and BiOCl, and the precipitate is increased by tartaric acid. Na_2CO_3 with effervescence, white basic carbonate. $HCl + H_2S$ dark brown Bi_2S_2, soluble in HNO_3.KOH and NH_4OH white hydroxide. $K_2Cr_2O_7$, an orange precipitate of Bi_23CrO_4 soluble in HNO_3. K_2SnO_3 a black precipitate. On charcoal with Na_2CO_3, in reducing flame, gives beads of brittle reddish-white bismuth, with slight yellow incrustation. Bismuth is weighed as Bi_2O_3, containing 89.74 per cent. of

metal. *N.B.* To metals precipitated by chlorides should be added Bi, in solutions of nitrate.

Lead oxide PbO. **Lead sulphide** PbS, blue-black, soluble in hot HNO_3. Already given at p. 1, under heading of precipitates by HCl. **But**, in dilute solutions HCl occasions no precipitate, as $PbCl_2$ is soluble in much water. Indeed the **solubility** of $PbCl_2$ **in water**, renders it **separable** from insoluble Hg_2Cl_2 and AgCl. Both $PbCl_2$ and AgCl are soluble in HCl, but water precipitates AgCl again, soluble in NH_3. If lead should be found in Group II. B, excess of dilute sulphuric acid will at once distinguish it from all the other metals of Groups I. and II. Further tests: **KI** and $K_2Cr_2O_7$; lead chromate **soluble** in **KOH**. **Lead** is weighed as **lead sulphate** $PbSO_4$, containing 68.32 per cent. of metal.

12. **Cupric oxide CuO, black**; HYDROXIDE $Cu(OH)_2$, **light-blue**. Salts are **colored, green** or **blue**. Chief soluble salts: $CuSO_4$, $5H_2O$; $CuCl_2,2H_2O$; $Cu2NO_3,6H_2O$. Acid reaction, Na_2CO_3, blue $Cu(OH)_2,CuCO_3$ sol. with **deep blue** color in NH_3, and to colorless solution in potassium cyanide. **HCl** changes **blue** sol. of $CuSO_4$ to **green**. **HCl + H_2S brown-black** prec. *slightly* soluble both in $(NH_4)_2S_2$, and even in H_2S. When large excess of mineral acid present, no prec. by H_2S until water added. **KOH blue** precipitate $Cu(OH)_2$; into black CuO when boiled. Glucose first added, and then KOH in excess, reduces Cu on heating to **red** cuprous oxide Cu_2O. **NH_4OH**, first a **greenish-blue** precipitate of basic salt; on excess, **deep blue** solution of $CuSO_4,4NH_3$, H_2O. **KCNS**, together with K_2SO_3 precipitates white cupric sulphocyanide. **K_4Cfy, red-brown** Cu_2Cfy, or coloration. **K_2HAsO_3, green CuHAsO$_3$. Iron** deposits **Cu**, especially in presence of free acid. On **charcoal**, with Na_2CO_3, in inner flame, a bead of copper is obtained. Salts of copper, in inner flame, give **emerald-green** color: the chloride, **azure-blue**. Borax-bead, **green** whilst hot, blue when cold. **Copper** is estimated as **cupric oxide**, which contains 79.85 per cent. of metal. By means of $(NH_4)_2CO_3$ in excess, it is **separated** from Bi and Cd.

13. **Mercuric oxide HgO**; red or yellow-red,—**black** when heated, and volatilizing as Hg + O. Soluble salts colorless. **$Hg2NO_3$**, very acid. **$HgCl_2$**, the chloride, or "corrosive sublimate," faintly acid. **Na_2CO_3**, heavy **red-brown** $2HgO,HgCO_3$: no precipitate in mercuric cyanide. HCl separates HCN. **HCl + H_2S**, the latter slowly added, **detects Hg** by formation of first white **chloro-sulphide**, $2HgS,HgCl_2$, then **orange**, black HgS, soluble in aqua regia. **KOH, yellow HgO**. **NH_3** in $Hg2NO_3$, **yellow** HgO; **but** in **$HgCl_2$**, or in presence of NH_4Cl, white mercuric chloro-amide **NH_2HgCl**. **KI scarlet HgI_2**, soluble in excess. **$SnCl_2$** first Hg_2Cl_2 and then **Hg_2** in grey globules. With metallic copper, Hg separated as silvery mirror, volatilized

by heat. Heated with Na_2CO_3 in glass tube, **Hg** volatilizes. **Mercury** may be weighed as **mercury**, as **mercurous chloride**, Hg_2Cl_2, containing **84.92** per cent. of **Hg**, and as **sulphide** HgS containing 86.21 per cent. of metal.

14. **Palladious oxide PdO, black.** HYDROXIDE $Pd(OH)_2$, **dark-brown**, by Na_2CO_3 from its salts. Salts mostly soluble. $PdCl_2$, **brown** or **reddish-brown**: decomposed by heat. $HCl + H_2S$, **black PdS**, soluble in hot HCl. **KOH, brown** basic salt, soluble. NH_3 **flesh-colored** precipitate, soluble. **KI black** PdI_2 soluble. MERCURIC CYANIDE $HgCy_2$, **yellowish-white** $PdCy_2$ soluble in NH_4OH: thus may **Pd** be separated from all the metals except lead and cuprum. **On charcoal**, with Na_2CO_3 the salts yield spongy **Pd**. **Palladium** is estimated as **metal**.

15. **Ferric oxide** Fe_2O_3, **red-brown.** HYDROXIDE $Fe_2(OH)_6$ bulky **reddish-brown**. Salts acid, **yellow** or **yellow-red** or **red-brown**. Na_2CO_3 with effervescence, hydroxide with carbonate. **HCl** deepens the color. $HCl + H_2S$ reduces ferric to ferrous salts, but **sulphur** of white or **yellow** color is alone precipitated. Thus: $Fe_2Cl_6 + n\text{HCl} + H_2S = 2FeCl_2 + 2\text{HCl} + n\text{HCl} + S$. If then a whitish or yellowish precipitate, add NH_4OH to one portion, and this with the H_2S present will form NH_4HS and throw down **black FeS,H₂O**; to the other portion, add **potassium ferridcyanide**: Turnbull's **blue** will result. Look for Ferric in Group III.

N.B. If $HCl + H_2S$ gives no reaction, add NH_4OH: there is no precipitate,—pass on to GROUP V.

Chromic acid CrO_3, **crimson**, or **red yellow**, or **yellow**, when dilute. Deliquescent. Reddens litmus. Effervescence without precipitation, on addition of Na_2CO_3, and color **bright yellow**. Chromates of alkalies soluble: acid salts turned to **bright yellow** chromates by Na_2CO_3. $HCl + H_2S$ precipitates **Sulphur** from chromic acid, and changes the acid into a **salt of chromic oxide** with **bluish-green color**. (See chromic acid.) Solutions of Ferric chloride or acidulated potassium dichromate are excellent tests of the **quality** of solutions of **hydrogen sulphide**.

Group III. Metals (not precipitated by Hydrogen chloride, nor by hydrogen sulphide in acid solutions) **precipitated in neutral solutions containing much ammonium chloride by ammonic hydrate in excess, as hydroxides.** 15. **Ferric oxide** Fe_2O_3. 16. **Manganic oxide** Mn_2O_3. 17. **Aluminum oxide** Al_2O_3. 18. **Chromic oxide** Cr_2O_3. **[Glucinum oxide GO.]**

15 *bis.* **Ferric oxide** Fe_2O_3; **red-brown.** HYDROXIDE $Fe_2(OH)_6$, **red-brown.** Salts **red-brown** or **yellow**, very intense. Chief salts: **Ferric chloride** Fe_2Cl_6. **Ferric sulphate** $Fe_2 3SO_4, 9H_2O$. **Ferric nitrate** $Fe_2 6NO_3, 12H_2O$. Acid reaction. Colored solu-

tions. Na_2CO_3, red ferric hydroxide and basic carbonate; soluble in $NaHCO_3$ to red solution. **HCl** increases the reddish-yellow tinge. **HCl** + H_2S reduces to Ferrous salt and precipitates yellow sulphur. Thus: $Fe_2Cl_6 + nHCl + H_2S = 2FeCl_2$ in solution $+ 2HCl + nHCl + S$. $NH_4Cl + NH_4OH$, red-brown ferric hydroxide $Fe_2(OH)_6$. $(NH_4)_2S_2$ black $Fe_2S_3.3H_2O$. **KOH**, red-brown hydroxide. NH_4OH, precipitates also hydroxide. K_4Fcy, precipitates prussian blue $Fe_4Fe_3Cy_{18}.18H_2O$. **KCNS**, gives blood-red solution. Tincture of galls produces blue-black ink. On charcoal, a dull-black powder attracted by magnet. Borax gives a bead varying in color from yellow to dark-red. Iron is weighed as Fe_2O_3 containing 70 per cent. of metal.

[16. Manganic oxide Mn_2O_3, blackish-brown. Salts deep-red and decomposed by heat into salts of MnO.]

17. Aluminum oxide Al_2O_3, white; HYDROXIDE $Al_2(OH)_6$ white, gelatinous, soluble in **KOH** (in which ferric oxide is insoluble). Soluble salts colorless, and acid to test-paper (except in aluminates which are strongly alkaline, and precipitated at first by HCl). CHIEF SALTS: Potassium, Sodium and Ammonium ALUMS. E.g. $K_2Al_2.4SO_4.24H_2O$. ALUMINUM SULPHATE $Al_2.3SO_4.18H_2O$: from its solution, K_2SO_4 precipitates alum. Na_2CO_3, white gelatinous precipitate of $Al(OH)_6$. **HCl** + H_2S no reaction. $NH_4Cl + NH_3$ white gelatinous hydroxide. **KOH** white $Al_2(OH)_6$, soluble in excess. Na_2HPO_4 white aluminum phosphate, not soluble in acetic acid even when heated. $(NH_4)_2S_2$, white $Al_2(OH)_6$ soluble in KOH. On charcoal heated strongly, and moistened with Co_2NO_3 and re-heated, yields Thénard's blue. Aluminum is weighed as alumina Al_2O_3, containing 53.39 per cent. of metal.

18. Chromic oxide Cr_2O_3, green. HYDROXIDE $Cr_2(OH)_6$, blue-green, soluble in KOH to green solution. Salts have a violet or green color. Soluble salts redden litmus. Chief salt: CHROME ALUM $K_2Cr_2.4SO_4.24H_2O$. Na_2CO_3, bluish grey-green basic carbonate, somewhat soluble. **HCl** + H_2S no reaction. $NH_4Cl + NH_3$ bluish-green $Cr_2(OH)_6$ soluble with peach-blossom tint in very large excess. $(NH_4)_2S_2$ bluish-green $Cr_2(OH)_6$, soluble with green color in KOH. **KOH** blue-green $Cr_2(OH)_6$, soluble with emerald-green color, and again separable on boiling. If PbO_2 boiled with solution of $Cr_2(OH)_6$ in KOH, yellow $PbCrO_4$ is obtained, which can be precipitated by neutralizing with acetic acid. Fused with Na_2CO_3 and KNO_3, yellow chromate is obtained. The borax-bead is colored green; so is also microcosmic salt. Chromium is weighed as Cr_2O_3, containing 68.63 per cent. of metal.

[19. Glucinum or Beryllium oxide GO, white: HYDROXIDE $G(OH)_2$ flocculent, soluble in KOH, and re-precipitated on boiling. Displaces NH_3 slowly from its salts, and dissolves in

NH_4Cl as chloride. Salts alkaline to test-paper. **Na_2CO_3** white **GCO_3**, considerably soluble. $NH_4Cl + (NH_4)_2CO_3$ no precipitate. **KOH** white hydroxide; soluble, but re-precipitated by NH_4Cl. **$(NH_4)_2S$** white flocculent hydroxide. Oxalic acid and oxalates no precipitate. **$(NH_4)_2CO_3$**, white, soluble in excess.]

Group IV. **Metals** (not precipitated by HCl as are **Pb,Hg_2** and **Ag** in Group I., nor by $HCl + H_2S$ as are **As, Sb, Sn, Sn_2, Au, Pt, Cd, Bi, Hg, Cu, Pd** in Group II., nor by $(NH_4)_2S_2$, not as sulphides, but as hydroxides, as are **Mn_2, Fe_2, Cr_2, Al_2, G**) precipitated by **$(NH_4)_2S_2$ in presence of ammonium chloride, as sulphides.** Includes zinc, manganous, ferrous, cobaltous, nickel [uranous and uranic]. **Zinc sulphide ZnS,H_2O** white. **Manganous sulphide MnS,H_2O,** flesh-colored. **Ferrous sulphide FeS,H_2O,** black. **Cobaltous sulphide** CoS,H_2O, black. **Nickel sulphide** NiS,H_2O black. [**Uranous sulphide** US, black, and **Uranic sulphide** U_2S_3 yellowish-brown.]

20. **Zinc oxide ZnO**, white. Hydroxide $Zn(OH)_2$, white and soluble in KOH. Soluble salts colorless. Chief salts; **$ZnSO_4$, $7H_2O$**; **$ZnCl_2$**; acid to test-paper. **Na_2CO_3** immediate white $ZnCO_3$. $HCl + H_2S$ no reaction. $NH_4Cl + NH_3$ no reaction, unless NH_4Cl in too small quantity, then white gelatinous hydroxide soluble in excess. **$NH_4Cl + (NH_4)_2S_2$**, white ZnS, H_2O soluble in HCl. **KOH**, white hydroxide, soluble. **NH_4OH,** white hydroxide, soluble; no precipitate in presence of free acids or ammoniacal salts. **$(NH_4)_2CO_3$**, white carbonate, soluble. **K_4Fcy,** white, gelatinous, Zn_2Cfy. **K_6Fcdy brownish-yellow.** With **Na_2CO_3** in reducing flame, the charcoal incrusted with yellow ZnO whilst hot, white on cooling. **ZnO** or salts strongly heated, and then moistened with **Co_2NO_3**, on reheating **green** (Rinman's green). **Zinc** is weighed as **ZnO**, containing 80.24 per cent. of zinc.

21. **Manganous oxide, MnO, light-green;** hydroxide white, browning on exposure to air. Soluble salts colorless, or pale pink. Neutral or faintly acid. Chief soluble salts; **$MnSO_4$, $7H_2O$** and **$MnCl_2$, $4H_2O$**. **Na_2CO_3**, white precipitate of $MnCO_3$, H_2O. $HCl + H_2S$ no reaction. $NH_4Cl + NH_4OH$ no precipitate, but the solution browns on exposure to air from formation of MnO,Mn_2O_3. **$NH_4Cl + (NH_4)_2S_2$, flesh-colored** precipitate of **MnS,H_2O** browning on exposure, and soluble in HCl or HNO_3. **KOH**, white MnO,H_2O browning. **NH_4OH,** hydroxide, soluble in large excess, but easily in presence of ammoniacal salts. **$(NH_4)_2CO_3$**, white $MnCO_3,H_2O$ soluble in ammoniacal salts. **K_4Fcy,** reddish white Mn_2Fcy. **K_6Fcdy, brown** Mn_3Fcdy. On charcoal, or platinum with **Na_2CO_3**, in the outer flame, **green** manganate. **Borax-bead** becomes amethystine on cooling, when heated in outer flame with manganese compounds. **Micro-**

oosmio salt, similar result. **Mn** is weighed as Mn_3O_4, containing 72 per cent. of manganesium.

22. **Ferrous oxide** FeO, **black.** Hydroxide $Fe(OH)_2$ white, changing when moist into **blue-green**, and finally **red.** Salts more or less **sea-green.** Faintly acid. Chief salt: Ferrous sulphate $FeSO_4,7H_2O$. Na_2CO_3, whitish precipitate of $FeCO_3$, when free from ferric salt: then more or less tinted. **HCl** changes **color to yellow.** $HCl + H_2S$ no reaction, except a ferric salt present. $NH_4Cl + NH_4OH$ no precipitate, but on exposure Ferrous-ferric hydrate of more or less red color begins to separate. $NH_4Cl + (NH_4)_2S_2$ **black** FeS,H_2O, soluble in HCl or HNO_3. **KOH** whitish hydroxide, immediately changing to **blue** or **bluish-green,** and slowly, on the surface to **red.** NH_4OH, whitish hydroxide, rapidly becoming **bluish-green** from absorption of oxygen, largely soluble in excess and not precipitate in presence of ammoniacal salts. K_4Cfy **bluish-white** $K_2Fe_2Cfy_2$, rapidly blueing. If ferric salt present, more or less blue. K_6Fcdy, **Turnbull's blue.** **KCNS** no change, except ferric salt present. **Charcoal** test &c., see 15. **Ferric oxide.** **Iron** is weighed as Fe_2O_3, containing 70 per cent. of ferrum. **N.B.** A ferrous salt is changed by HNO_3 or by aqua regia into a ferric salt, after which it is discovered and removed under Group III. by $NH_4Cl + NH_4OH$.

23. **Cobaltous oxide** CoO, **grey.** Hydroxide $Co(OH)_2$, **dirty-red.** Salts **blue** or **red.** Chief salts: $CoSO_4,7H_2O$; $Co2NO_3$, $6H_2O$; $CoCl_2.6H_2O$. Acid to test-paper. Na_2CO_3, **lilac** precipitate $3CoO.2CoCO_3,4H_2O$. **HCl** may turn **red** salt **blue.** $HCl + H_2S$ no reaction. $NH_4Cl + NH_3$, no precipitate, but **reddish-brown** on exposure. $NH_4Cl + (NH_4)_2S_2$, as **black** CoS,H_2O, soluble in aqua regia. **KOH blue** basic salts, turning **green** on exposure, owing to absorption of oxygen: into **pale-red hydroxide** on boiling. NH_4OH, **blue** basic salt, readily soluble in excess, with **greenish** color, **browning** on exposure: ultimately **red.** $(NH_4)_2CO_3$, **peach-colored** basic carbonate, readily soluble with **magenta** color. K_4Cfy, **greenish** precipitate of Co_2Cfy. K_6Fcdy **brownish-red** precipitate. Addition of tartaric acid, then of NH_4OH, and K_6Fcdy, yields a deep yellowish-red color. Thus may **Co** be detected in presence of Ni. KNO_2, together with acetic acid, yields after a time a **bright-yellow** precipitate of cobalt sesquioxide and potassium nitrite. **KCN brownish-white** $CoCy_2$, easily soluble, and precipitated by HCl: **not precipitated if cobalticyanide produced.** **On charcoal,** similar to iron, but more metallic. **Borax** bead coloured blue both in inner and outer flame. **Microcosmic salt,** similar reaction. **Cobalt** is either **weighed** as metal, or as Co_3O_4, containing 73.44 per cent. of metal.

24. **Nickel oxide** NiO, **green.** Hydroxide $Ni(OH)_2$, unripe

apple-green. Soluble salts redden litmus. Chief soluble salts: $NiCl_2,9H_2O$. $NiSO_4,7H_2O$. $Ni_2NO_3,6H_2O$. Green in color. Na_2CO_3, green basic carbonate. $HCl + H_2S$ no reaction. $NH_4Cl + NH_3$, plum-colored liquid. $NH_4Cl + (NH_4)_2S_2$ black sulphide NiS,H_2O, giving brown coloration to liquid. Readily soluble in aqua regia. KOH precipitates apple-green hydroxide $Ni(OH)_2$. NH_4OH, greenish turbidity, soluble to a plum-colored fluid. No precipitate in free acids, or in presence of salts of ammonium: KOH re-precipitates $Ni(OH)_2$. $(NH_4)_2CO_3$. green carbonate, readily soluble to greenish-blue fluid. K_4Cfy, greenish-white Ni_2Cfy. K_6Fcdy, yellowish-brown Ni_3Fcdy. KCN, yellowish-green $CoCy_2$, soluble with brownish-yellow color, and re-precipitated on addition of acids. On charcoal, reduced, as is the case with iron and nickel. Borax bead in outer flame reddish-yellow while hot, paler on cooling. Nickel is weighed as NiO, containing 78.67 per cent. of metal.

25. [Uranous oxide UO. Hydroxide $U(OH)_2$, reddish-brown. Salts green. $(NH_4)_2S_2$ black US. KOH, blackish-brown hydroxide, changing to yellow from formation of uranic salt. NH_4OH acts similarly. Uranous salts absorb O, and are instantly changed into uranic by HNO_3.]

26. [Uranic oxide U_2O_3 brick-red. Hydroxide $U_2O_3,2H_2O$, greenish-yellow. Salts yellow. Na_2CO_3, yellow granular, soluble, double carbonates. $(NH_4)_2S_2$, yellowish-brown sulphide. NH_4OH yellow ammonium uranate. K_4Fcy, brown.]

Group V. Metals (not precipitated by HCl as are Ag, Pb and Hg_2,—nor by $HCl + H_2S$ as are As, Sn, Sn_2, Sb, Au, Pt, Hg, Bi, Pb, Cd, Cu, Pd,—nor by NH_4OH in presence of NH_4Cl as are Al_2, Mn_2. Fe_2, Cr_2 and Be,—nor by H_2S even in presence of NH_4Cl as are Fe, Co, Ni, Mn, Zn) which are precipitated by Na_2CO_3 as carbonates, soluble in free acids as respective salts. Barium, as carbonate $BaCO_3$, and Strontium as carbonate $SrCO_3$, Calcium as carbonate $CaCO_3$, and Magnesium as carbonate $MgCO_3$.

27. Barium oxide BaO, white. Hydroxide $Ba(OH)_2$, white, and soluble in water. Its solution strongly alkaline, is precipitated white by the CO_2 of the breath as well as by Na_2CO_3, and yields Ag_2O of grey-brown color, soluble both in HNO_3 and in NH_4OH. Further $Ba(OH)_2$ is precipitated immediately by $CaSO_4$.—Soluble salts colorless. Neutral. Chief salts: Ba_2NO_3. $BaCl_2,2H_2O$. HCl no reaction unless concentrated, and then of the salt, soluble in more water. $HCl + H_2S$ no reaction. $NH_4Cl + NH_4OH$ no reaction unless ammonia contains carbonate. $NH_4Cl + (NH_4)_2S_2$, no reaction, unless ammonium sulphate present in the latter. $(NH_4)_2CO_3$, white $BaCO_3$. KOH, white hydroxide, in concentrated solutions. NH_4OH no reaction. $CaSO_4$, immediate white precipitate of

$BaSO_4$: all soluble sulphates precipitate $BaSO_4$. $(NH_4)_2C_2O_4$, white BaC_2O_4, soluble in HCl. Na_2HPO_4 white $BaHPO_4$, very slightly increased by NH_4OH. $K_2Cr_2O_7$ yellow $BaCrO_4$, soluble in HCl, unless the test contains sulphate. $2HF,SiF_4$ almost colorless BaF_2,SiF_4. Soluble salts impart greenish-yellow color to flame. Insoluble must be moistened with HCl, and then heated. Barium is estimated as $BaSO_4$ containing 65.66 BaO, insoluble in dilute acids and alkalies. $BaCl_2$ is insoluble in absolute alcohol: $SrCl_2$ is soluble.

28. **Strontium oxide SrO**, white. Hydroxide $Sr(OH)_2$, white, soluble and alkaline. Na_2CO_3 white $SrCO_3$: also precipitated white by the breath. $AgNO_3$, grey-brown Ag_2O, soluble in NH_3 and in HNO_3. Precipitated by $CaSO_4$ on heating. Soluble salts (except $SrCrO_4$ which is yellow) neutral or faintly acid. Chief salts: $Sr_2NO_3,5H_2O$. $SrCl_2,6H_2O$, deliqueseent. $(NH_4)_2CO_3$, white $BaCO_3$. KOH white $Sr(OH)_2$ soluble in boiling water. NH_4OH of course no reaction. $CaSO_4$, white $SrSO_4$ on long standing, or immediate when heated. Soluble sulphates precipitate $SrSO_4$. Both Ba and Sr thus removed from solutions containing Ba, Sr, and Ca. $(NH_4)_2C_2O_4$ white SrC_2O_4. Carmine color to flame. Strontium weighed as $SrSO_4$ containing 56.52 per cent. of SrO.

29. **Calcium oxide CaO**, white. Hydroxide $Ca(OH)_2$, white and soluble in 700 parts of cold and 1280 parts of boiling water. "Lime-water." Alkaline. Precipitated by the breath (CO_2), as well as by Na_2CO_3. $AgNO_3$, grey-brown Ag_2O, soluble in HNO_3 and in NH_4OH. Chief salts: $CaCl_2,6H_2O$, deliquescent. $CaSO_4,2H_2O$ soluble in 400 water. Ca_2NO_3, $4H_2O$. Ca_2ClO_3. (Chloride of lime $2CaOCl_2$, dissolves as $CaCl_2 + Ca_2ClO$,—therefore two salts, and not given at the examinations.) $(NH_4)_2CO_3$, white $CaCO_3$. The test should be added very sparingly on account of the solubility of calcium bi-carbonate, which would be precipitated on boiling. $CaSO_4$ of course no reaction, even on boiling: absence of barium and strontium salts. H_2SO_4 in concentrated sols., white crystalline $CaSO_4,2H_2O$; precipitate hastened by alcohol. $(NH_4)_2C_2O_4$ white CaC_2O_4, quite insoluble in acetic acid. This test is decisive, if absence of Ba and Sr proved by $CaSO_4$. Soluble salts, yellowish-red color to flame. Calcium is weighed as $CaCO_3$, containing 56 per cent. of CaO, or as $CaSO_4$ containing 41.18 of CaO.

30. **Magnesium oxide MgO**, white. Hydroxide $Mg(OH)_2$, alkaline, requiring 5142 parts of ice-cold, and 36,000 parts of boiling water. Chief salts: $MgSO_4,7H_2O$. $MgCl_2.6H_2O$. $Mg_2NO_3,6H_2O$. $(NH_4)_2CO_3$, after a few moments, a constantly increasing white precipitate of basic magnesium carbonate. No precipitate in presence of free acids, or of salts of ammonium. $NaHCO_3$, a precipitate on heating: a Mg salt therefore a test

for a bi-carbonate. NH_4OH, white hydroxide, slowly and incompletely: in presence of ammoniacal salts or of free acids, *no precipitate*. $NaHPO_4$, added to a solution containing $NH_4Cl + NH_4OH$, an immediate white crystalline $MgNH_4PO_4$, $6H_2O$. KOH, NaOH, LOH, $Ba(OH)_2$, $Sr(OH)_2$ and $Ca(OH)_2$, precipitate $Mg(OH)_2$. $(NH_4)_2C_2O_4$ no precipitate at all (except in very concentrated solutions after a time). No color to flame: MgO, rose-colored when ignited on platinum with Co_2NO_3. Magnesia is weighed as MgO, containing 60 per cent. of Mg, and as $Mg_2P_2O_7$ containing 36.21 per cent. of MgO.

Group VI. Metals not precipitated by Na_2CO_3, nor by any of the preceding tests. Include kalium, natrium, lithium, caesium, rubidium, and ammonium.

31. Ammonium hydroxide NH_4OH only known in solution. Evolves NH_3 as a gas of ammoniacal (!) odor, blueing red litmus, and forming white fumes of NH_4Cl with a glass rod steeped in HCl. No residue on platinum. $AgNO_3$ grey-brown Ag_2O, easily soluble. No effervescence, when diluted, on addition of HCl. Nessler's test, yellow or brown NHg_2I,H_2O. With $2HCl + PtCl_4$, yellow $2NH_4Cl,PtCl_4$. Salts: all soluble, except $2NH_4Cl,PtCl_4$ and with difficulty ammonium hydrogen tartrate. Chief salts. NH_4Cl. $(NH_4)_2SO_4$. NH_4NO_3. NH_4NO_2. $2[(NH_4)_2CO_3]$ CO_2. Solutions neutral, alkaline or acid. Na_2CO_3 boiled with any salt of ammonium, even when quite neutral or acid, evolves ammonium carbonate, smells of NH_3, fumes with HCl and blues red litmus. KOH, $Ca(OH)_2$ and all intermediate hydroxides displace NH_3 which is recognized as above. $PtCl_4$, yellow $2NH_4Cl,PtCl_4$. Salts volatilized by heat, with or without decomposition. Fixed acids remain.

32. Potass-oxide K_2O, grey. Hydroxide KOH, white, fusible, partially volatile, with violet color to flame. Strongly alkaline. Na_2CO_3 no reaction, even on boiling (absence of NH_4 salts). $AgNO_3$ grey-brown Ag_2O, insoluble in excess. Nearly all salts soluble, except $2KCl,PtCl_4$ and $2KF,SiF_4$. Chief salts: K_2CO_3, $2H_2O$. $KHCO_3$. K_2SO_4. KCl. $KClO_3$. KI. KBr. Solutions colorless, except in the case of chromates (yellow), dichromates (yellow-red), ferrocyanide (yellow), &c. &c. Na_2CO_3 no reaction, even on boiling. After proving absence of NH_4 salts: $HCl + PtCl_4$ yellow $2KCl,PtCl_4$, nearly insoluble in alcohol-ether. Stirring promotes the precipitation Concentration in dilute solutions necessary. Tartaric acid $H_2C_4H_4O_6$, in excess, white crystalline $KHC_4H_4O_6$, soluble in alkalies, and in acids. $2HF,SiF_4$ nearly white $2KF,SiF_4$. The violet tint of flame best observed through blue glass.

33. Lithium oxide L_2O, white. Hydroxide LOH, white, least soluble of alkalies. Alkaline. Chief salt: LCl, deliques-

eent. $2HCl,PtCl_4$ no precipitate. $H_2C_4H_4O_6$ no precipitate. In concentrated solutions Na_2CO_3 white L_2CO_3: in dilute, none. Na_2HPO_4, white L_3PO_4, soluble in dilute acids. In blowpipe flame, a purplish red color.]

[34. **Rubidium oxide** Rb_2O, white. HYDROXIDE RbOH, white, very soluble, alkaline. Resembles KOH, but more electro-positive. **RbCl**, very deliquescent. Na_2CO_3 no reaction. $2HCl + PtCl_4$, very sparingly soluble $2RbCl,PtCl_4$. Flame violet.]

[35. **Caesium oxide.** Cs_2O white. HYDROXIDE **CsOH** white, deliquescent, strongly alkaline. Na_2CO_3 no reaction. $2HCl + PtCl_4$ yellow $2CsCl,PtCl_4$. Flame violet.]

36. **Sodium oxide** Na_2O: grey. HYDROXIDE NaOH white, very deliqueseent, alkaline, partially volatile. **Yellow** color to flame. Na_2CO_3, of course no reaction. $AgNO_3$, **grey-brown** Ag_2O, soluble in NH_4OH and in HNO_3. Salts all soluble, except $Na_2H_2Sb_2O_7$ which is precipitated by $K_2H_2Sb_2O_7$.

Recapitulation.

GROUP I. **HCl gives a precipitate.** $PbCl_2$. Hg_2Cl_2. AgCl. (TlCl). 1. $PbCl_2$ soluble in boiling water. KOH white $Pb(OH)_2$, soluble. 2. Hg_2Cl_2, insoluble, black by NH_3 as NH_2Hg_2Cl. KOH black Hg_2O. 3. AgCl insoluble, dissolved in excess of NH_3, and re-precipitated by HNO_3. KOH, grey-brown Ag_2O.

GROUP II. **HCl + H_2S a precipitate.** Includes **As, Sn_2, Sn, Sb, Pt, Au, Cd, Bi, Pb, Cu, Hg** and **Pd.**

A. Sulphides soluble in ammonium sulphide.

As_2S_3. SnS_2. SnS as SnS_2. Sb_2S_3. [PtS_2. Au_2S_3.]

As_2S_3 is immediately precipitated as bright yellow As_2S_3, soluble in $(NH_4)_2CO_3$; as arsenite, gives yellow Ag_3AsO_3 and green $CuHAsO_3$. An **arsenate**, with difficulty as $As_2S_3 + S_2$, soluble in $(NH_4)_2CO_3$. Ag_3AsO_4 liver-brown. NH_4MgAsO_4, $6H_2O$ white, crystalline. 5. SnS_2,H_2O is **yellow**, insoluble in $(NH_4)_2CO_3$. In salts, Na_2CO_3 white pr. 7. SnS, H_2O is coffee-brown, soluble by heat in $(NH_4)_2S_2$, and re-precipitated by HCl as **yellow** $SnS_2.H_2O$. 6. Sb_2S_3 orange-colored, soluble in strong HCl, insol. in $(NH_4)_2CO_3$.

B. Insoluble in $(NH_4)_2S_2$.

CdS. Bi_2S_3. PbS. CuS. HgS. [PdS.]

10. CdS bright light yellow. Hydroxide soluble in NH_4OH. 11. Bi_2S_3, dark-brown. BiO_2H, white, insol. in KOH and in NH_4OH. Chromate, orange. insol. in KOH. PbS, blue-black. $Pb(OH)_2$ sol. in KOH. $PbCrO_4$ yellow, sol. in KOH. Dilute

sulphuric acid, white $PbSO_4$. 12. **CuS** brown-black. Salts blue or green. NH_4OH deep-blue in excess. K_4Cfy red-brown Cu_2Cfy. 13. **HgS** black insol. in HNO_3: carefully prec. by H_2S, white, yellow, orange, black. KI scarlet. $SnCl_2$ gives Hg_2Cl_2 and 2Hg.

GROUP III. **In presence of NH_4Cl, by NH_4OH as hydroxides. $Fe_2(OH)_6$; [$Mn_2(OH)_6$]; $Al_2(OH)_6$; $Cr_2(OH)_6$. [BeO or GO].** 15. **$Fe_2(OH)_6$**, red-brown, bulky, insol. in KOH. K_4Cfy, Prussian-blue. $(NH_4)_2S_2$ **Fe_2S_3**,$3H_2O$ black. [17. **$Al_2(OH)_6$**, white, soluble in KOH. Salts colorless. 18. **$Cr_2(OH)_6$**, bluish-green, soluble with emerald-green color in KOH.

GROUP IV. **Even in presence of NH_4Cl, $(NH_4)_2S_2$ precipitates as sulphides ZnS, MnS, FeS, CoS, NiS, [US. U_2S_3].** 20. **ZnS, H_2O**, white, insoluble in KOH. $(NH_4)_2CO_3$, white. KOH, white. NH_4OH white, soluble without color. 21. **MnS,H_2O**, flesh-color, browning, sol. in acetic acid even. KOH white, insoluble, browning. NH_4OH, white, sol. browning. 22. **FeS, H_2O**, black, very soluble in HCl. K_6Fcdy, Turnbull's blue. K_4Cfy bluish-white. 23. **CoS,H_2O**, black, insoluble in weak HCl. Solutions pink, red or blue,—on dilution pink. **NH_4OH** in excess to reddish-brown liquid. Na_2CO_3 lilac precipitate. K_6Fcdy brownish-red. K_4Cfy greenish. 24. **NiS,H_2O**, black, with difficulty soluble in HCl. Solutions green. NH_4OH in excess, plum-colored solution. K_6Fcdy yellowish-brown. K_4Cfy greenish-white.

GROUP V. **Metals precipitated as carbonates by Na_2CO_3. $BaCO_3$. $SrCO_3$. $CaCO_3$. $Mg(OH)_2$,$MgCO_3$.**

A. $(NH_4)_2CO_3$ precipitates Ba, Sr and Ca.

27. **$BaCO_3$**, white. $CaSO_4$, immediate pr. of $BaSO_4$. Yellow-green color to flame. $2HF$,SiF_4 white precipitate. 28. **$SrCO_3$**, white. $CaSO_4$ a precipitate after standing or on heating. Crimson color to flame. 29. **$CaCO_3$** white. $CaSO_4$ no reaction. $(NH_4)_2C_2O_4$ white, insoluble in acetic acid.

B. $(NH_4)_2CO_3$ no precipitate, Mg.

30. **$MgCO_3$**, white. NH_4OH white Mg(OH): no prec. in acid solutions. NH_4Cl+NH_4OH no prec. but on addition of Na_2HPO_4, white, crystalline NH_4MgPO_4, $6H_2O$.

GROUP VI. **Potassium group, including NH_4, K, L, Rb, Cs, and Na.**

31. **NH_4OH**, alkaline, odorous of hartshorn, blues red litmus and fumes with HCl. Salts decomposed by Na_2CO_3. Volatile. $PtCl_4$, yellow $2NH_4Cl.PtCl_4$. 32. **K** looked for when absence of NH_4 salt proved. Violet color to flame. $PtCl_4$ yellow 2KCl, $PtCl_4$. 36. **Na.** Salts: yellow color to flame. Only precipitated by $K_2H_2Sb_2O_7$.

Examination for acids.

Organic acids and salts, except oxalates, acetates and formates, blacken on heating. Nearly all salts of Group VI. are soluble in water. The nitrates, chlorates, sulphates, chlorides, bromides, iodides, cyanides and acetates are mostly soluble in water. It is advisable to moisten a solid with $(NH_4)_2S_2$ to ascertain at once the "suspicion" of metals belonging to Groups I., II., III., and IV. The condition as to "neutral," "alkaline," or "acid" is of first importance, and so is also the effect of heating on platinum. As with the bases, so with the acids: there are certain **Group-tests**, but they are not so definite. Students should carefully notice the amount of a precipitate, whether copious, scanty, or a mere turbidity, so as not to mistake mere traces for a substance present in quantity. When a solution is very dilute, it is advantageous to concentrate by evaporation. If Na_2CO_3 has produced a precipitate, continue the addition till a slight excess is present (alkaline and no further precipitate), warm, filter, neutralize the filtrate carefully with HCl or HNO_3 (*not forgetting the addition of these acids*); examine the filtrate for the acids. The precipitate of carbonate or hydroxide may be washed with distilled water, dissolved in HCl or HNO_3, and tested for the metal. Further, in testing for organic acids the solution, if not neutral, should be made so by careful addition of dilute ammonia, or of dilute HCl, HNO_3 or acetic acid: excess of NH_3 is removed by boiling. Many of the heavy metals are best removed by H_2S in excess, and filtration.

In the analysis of simple solutions, which is alone required in the Examinations of the University of London, of the Royal College of Physicians, and of Apothecaries Hall, these difficulties do not occur. The acids and salts in brackets and unnumbered are not there required.

A. **Salts visibly or detectably decomposed by HCl.** Includes **carbonates, sulphides, sulphites, thiosulphates,** [hydrosulphites, dithionates, trithionates, tetrathionates, pentathionates, sulphocarbonates] **nitrites, chlorates, hypochlorites,** [iodates, bromates, hypobromites] **cyanides, ferrocyanides, ferricyanides, sulphocyanides, acetates, oxalates, silicates,** [titanates, tungstates, molybdates] **borates, chromates, arsenites,** [sulpharsenites], **arsenates,** [sulpharsenates, antimonites, antimonates], **urates, hippurates, gallates, tannates, benzoates** [salicylates].

I. **Carbonates:** those of the alkaline metals alone soluble. Solutions colorless: alkaline to test-paper. Hydrogen-carbonates slightly alkaline. All bi-carbonates somewhat soluble, lose CO_2 when heated, and in the case of earthy carbonates

deposit insoluble carbonates. **HCl**, effervescence from inodorous CO_2, which can be decanted into a test-glass containing lime-water and yields precipitate of $CaCO_3$. **$BaCl_2$** white $BaCO_3$, soluble, with effervescence, in HCl or HNO_3. **$AgNO_3$**, white Ag_2CO_3, sol., with effervescence, in HNO_3, and soluble in NH_3. **$CaCl_2$** white $CaCO_3$. **$Pb_2C_2H_3O_2$** precipitates, "white-lead" $Pb(OH)_2$, $2PbCO_3$. Bi-carbonates, like **$NaHCO_3$**, **only** precipitate **$MgSO_4$** on heating, and give a dull-red prec. with $HgCl_2$; carbonates an immediate prec. with $MgSO_4$, and a yellow one with $HgCl_2$. On heating $NaHCO_3$, CO_2 is given off, and therefore a solution for testing can only be made in cold water. $CaCO_3,CO_2$, precipitated on boiling. Solution of H_2CO_3, turns litmus, "port-wine-red," evolves pearly bubbles on warming, prec. lime-water and leaves no residue.

II. **Sulphides.** Odorous of H_2S. **Alkaline** to test-paper: no sulphide can be present that does not turn red litmus blue. Those of Groups V. and VI. alone soluble in water. **HCl** evolves **H_2S**, which **blackens lead-paper**: in poly-sulphides **S** is precipitated at same time as **H_2S** evolved, the latter even with effervescence, odorous of putrid eggs. (In testing for AsH_3 or SbH_3, in putrid solutions, by paper soaked in $AgNO_3$, lead paper must first be used to prove absence of H_2S.) **$AgNO_3$**, black Ag_2S. **$FeSO_4$**, black FeS. **$SnCl_4$**, yellow $SnS_2,2H_2O$, **soluble in excess of the sulphide.** Free **H_2S**, recognized by odor, acid to test-paper, no reaction with HCl, no residue on heating. **Cl** prec. **S**; **Br** and I water are decolorized, with deposit of S and formation of HCl, HBr and HI. HNO_3 decomposes H_2S, and sulphides, with deposit of S. As the quality of H_2S solution is of great importance in testing, it should be added in excess to solution of $K_2Cr_2O_7$ into which H_2SO_4 has been introduced: it should become milky blue-green. $2K_2Cr_2O_7 + 8H_2SO_4 + 6H_2S = 2K_2Cr_2{}_4SO_4 + 14H_2O + 3S_2$.

III. **Sulphites.** Sulphites of alkalies alone soluble: the neutral are alkaline to test-paper, the acid salts are all somewhat soluble, redden litmus, and then bleach it. **HCl** evolves odor of burning brimstone, but **SO_2** so soluble, that effervescence rare. (N.B. The pungent odor of HCl might be mistaken for SO_2: in case of doubt, use H_2SO_4.) Add Zn to HCl solution, **H_2S** evolved. **$BaCl_2$** white **$BaSO_3$**, sol. in HCl in absence of sulphates,—a very rare case. **$AgNO_3$** white Ag_2SO_3; by heat into grey metallic silver, often with silver lustre. $Ag_2SO_3 + H_2O = H_2SO_4 + Ag_2$. Ferric salts **reduced** to Ferrous: $Fe_2Cl_6 + SO_2 + 2H_2O = FeSO_4 + FeCl_2 + 4HCl$. Arsenic acid **reduced** to Arsenious acid: $H_3AsO_4 + H_2SO_3 = H_3AsO_3 + H_2SO_4$. Solution of SULPHUROUS ACID, H_2SO_3 is odorous of burning brimstone, reddens and bleaches litmus, bleaches indigo and other colors; decomposes H_2S, with deposit of S. On **platinum** no residue.

IV. **Thiosulphates.** Salts of alkalies, of Ca and Sr soluble; alkaline to test-paper. $Na_2S_2O_3,5H_2O$, the common salt, **HCl** evolves SO_2, and in a few moments a yellow prec. of **S**. Thus:— $Na_2S_2O_3 + 2HCl = 2NaCl + H_2O + SO_2 + S$. **$AgNO_3$**, white $Ag_2S_2O_3$, rapidly **orange** and **black**: $Ag_2S_2O_3 + H_2O = H_2SO_4 +$ **Ag_2S**. **$Hg_2{}^2NO_3$**, **black** Hg_2S. AgCl readily soluble as $NaAgS_2O_3$. **$BaCl_2$** white BaS_2O_3. $Na_2S_2O_3,5H_2O$ fuses on **platinum**, evolves SO_2, burning with yellow flame, with blue and red tints on platinum: at last into Na_2SO_4. THIOSULPHURIC ACID non-existent in separate state.

[**Hyposulphites**, the real hydrosulphites. The free acid is a yellow liquid, HYPOSULPHUROUS ACID H_2SO_2, easily decomposing with liberation of Sulphur. Salts white or colorless, give immediately black Ag_2S, with **$AgNO_3$**. **HCl** gives yellow color, and after a time $S + SO_2$. They bleach vegetable colors more rapidly than other sulphur-acids.]

[**Dithionates.** DITHIONIC ACID $H_2S_2O_6$, colorless liquid, by concentration into $H_2SO_4 + SO_2$. **HCl** into $H_2SO_4 + SO_2$. All salts soluble.]

[**Trithionates.** TRITHIONIC ACID $H_2S_3O_6$. Salts mostly soluble. **HCl** into $H_2SO_4 + SO_2 + S$. **$AgNO_3$** yellow. $Hg_2{}^2NO_3$ black. Hg^2NO_3 white.]

[**Tetrathionates.** TETRATHIONIC ACID $H_2S_4O_6$: very unstable. **HCl** into $H_2SO_4 + SO_2 + S_2$. **$Hg_2{}^2NO_3$**, yellow.]

[**Pentathionates.** PENTATHIONIC ACID $H_2S_5O_6$, acid liquid, by **HCl** into $H_2SO_4 + H_2S + 2S_2 + 4SO_2$. Iodine water not decolorized.]

[**Sulphocarbonates**, analogous to carbonates. SULPHOCARBONIC ACID H_2CS_3. **HCl**, deep-brown oil H_2CS_3 separates. Boiled with water, the sulphocarbonates become carbonates.]

V. **Nitrites.** Mostly soluble. Nitrites of K, Na and NH_4, alkaline, colorless. **HCl** evolves nitrous fumes (really $NO + O = NO_2$) of **orange** color, HNO_3 being found in solution. **$AgNO_3$** white $AgNO_2$, black on heating. **$FeSO_4$**, olive-brown color, and NO_2 gas; to rich yellow color on heating. **$CuSO_4$**, **emerald-green** solution of Cu^2NO_2. **Starch-paste** and **KI**, with acetic acid even, **blue** iodide of starch.

For action of **HCl** upon **nitrates** and **nitric acid**, see XXXVII.

VI. **Chlorates.** **All soluble**: no precipitate with reagents, except of the distinctive basyl. **HCl** evolves euchlorine as green-yellow gas, coloring the solution yellow-green. On **platinum**, into chlorides; **then**, dissolved in water, acidulated with HNO_3 and $AgNO_3$ added, white, curd-like AgCl, soluble in NH_3 and insoluble in HNO_3. Deflagrate on charcoal.

VII. **Hypochlorites.** "Bleaching-powder" $2CaOCl_2$, the chief salt: dissolves as mixture of $CaCl_2 + Ca^2ClO$. Alkaline also very soluble. Odor of Cl_2; bleach vegetal colors. **HCl** gives

either HOCl or $Cl_2 + H_2O$. Boiled, into chloride and chlorate. $Pb_2C_2H_3O_2$, white, and on warming red and brown PbO_2. $MnCl_2$ black $MnO(OH)_2$.

[Iodates. Acid: HIO_3. Alkaline salts soluble, colorless. Deflagrate on charcoal. On platinum into iodides (soluble in water, and scarlet HgI_2 with $HgCl_2$). HCl brown I_2: soluble in chloroform with amethystine color, and giving with starch, blue iodide. $BaCl_2$, white Ba_2IO_3, soluble in HNO_3. $AgNO_3$, white $AgIO_3$, soluble in NH_3. H_2SO_3 reduces to iodide.]

[Bromates. Acid: $HBrO_3$. Colorless: alkaline salts readily soluble. Deflagrate on charcoal. On Platinum into bromides (p. 39). HCl and heat, orange vapors or blood-red drops in test-tube, soluble with orange color in $CHCl_3$, and forming orange bromide of starch. $AgBrO_3$ white. $Hg_2{}^2BrO_3$, white.]

[Hypobromites. Acid: HOBr. Reactions like bromates, but they bleach, and the soluble salts have always alkaline reactions.]

VIII. Cyanides. Soluble salts colorless. Alkaline to test-paper. Odorous of hydrocyanic acid CNH. HCl liberates CNH freely, volatile, precipitating $AgNO_3$. Chief salt: CNK, often containing K_2CO_3, when solution effervesces with HCl. $BaCl_2$ no reaction (in absence of K_2CO_3 and KCNO). $AgNO_3$ white, curd-like AgCN, soluble in boiling HNO_3, and in much NH_3. AgCN fuses; by heat gives $(CN)_2$, burning with peach-blossom colored flame. $FeSO_4$ red precipitate $KCy,{}^2FeCy_2$: add KOH, boil and then HCl in excess "Prussian blue" $Fe_4Fe_3Cy_{18},{}^{18}H_2O$ is formed. If only a trace, solution green. $(NH_4)_2S_2$ added and evaporated to dryness, leaves a sulphocyanide which gives blood-red coloration with Fe_2Cl_6. Free CNH completely volatile; acid; odor as of peach-kernels bruised. No residue on platinum. $AgNO_3$ white AgCN, sol. in boiling HNO_3. A strip of filtering paper, moistened with KOH, and suspended in tube where CNH escapes, gives "Prussian blue" reaction when placed in solution of $FeSO_4$, and HCl added. N.B. In HgC_2N_2, Hg not precipitated by Na_2CO_3; but HCl sets CNH free. Heated in tube, HgC_2N_2 gives Hg and C_2N_2, which burns with peach-blossom colored flame.

IX. Ferrocyanides. Chief salt $K_4FeCy_6,{}^3H_2O$. Slightly alkaline. Yellow. HCl, precipitates white or bluish-white H_4FeCy_6: in weak solutions no visible reaction, but probably blue tint. $AgNO_3$ white. $CuSO_4$, red-brown Cu_2Cfy. Fe_2Cl_6, Prussian blue $Fe_4Fe_3Cy_{18},{}^{18}H_2O$. $FeSO_4$ bluish-white $K_2Fe_2Cy_6$. Heated on platinum, cyanide formed. Test as under VIII. Distilled with dilute sulphuric acid, they yield CNH in the distillate.

X. Ferricyanides. Chief salt $K_6Fe_2Cy_{12}$: neutral, brownish-

green in color. **HCl** no visible reaction. **$AgNO_3$ orange**, insoluble in HNO_3, but readily in KCN and in NH_3. **Fe_2Cl_6**, only deepens the brown tinge. **$FeSO_4$**, "Turnbull's blue." Distilled with H_2SO_4, they yield CNH. Both the insoluble ferroeyanides and ferrieyanides are decomposed by boiling with NaOH, into the respeetive oxides, and soluble Na_4Cfy or Na_6Fedy. By fusion with KNO_3, CO_2 and N are evolved, and the respeetive metals obtained as oxides.

XI. **Sulphocyanides.** Chief salts: **KCNS** and **NH_4CNS**. Slightly alkaline. Colorless. **HCl** no visible reaetion. **$AgNO_3$** white, soluble in NH_3, not in dilute HNO_3. **$Pb_2C_2H_3O_2$**, white, very soluble in acetie aeid. **$CuSO_4$**, blaek $CuCsy_2$: in presence of $FeSO_4$ or H_2SO_3, white Cu_2Csy_2. **Fe_2Cl_6**, **blood-red** Fe_2Csy_6: eolor destroyed by $HgCl_2$; not by HCl. $Zn + H_2SO_4$, evolves **H_2S** and deeolorizes.

XII. **Acetates.** With **HCl**, by heat evolve acetie aeid (see D. p. 37).

XIII. **Oxalates** (see C. p. 35).

XIV. **Silicates.** Salts of alkaline metals alone soluble, eolorless, **alkaline.** **HCl** gelatinous H_4SiO_4 deposited. In dilnte solutions no visible reaction, as ortho-silieie aeid remains dissolved; on evaporation to dryness, heating, and boiling with dilute HCl, **SiO_2** is left as a white, amorphous, insolnble substanee. **NH_4Cl**, white H_4SiO_4, with odor of NH_3. **$BaCl_2$**, white. **$AgNO_3$**, white. (A dialysed solution is gelatinized by HCl, and is only faintly acid to test-paper.)

[**Titanic acid**, whieh resembles SiO_2, is separated from SiO_2 by fusion with $KHSO_4$, and subsequent treatment with water, SiO_2 remains undissolved.]

[**Tungstates** of alkalies and magnesia alone soluble. Sols. eolorless, alkaline. **HCl** white gelatinous H_2WO_4, turning yellow on boiling, and insoluble in excess of HCl, of HNO_3 and of H_2SO_4; soluble in ammonie hydrate. $(NH_4)_2S_2$ + HCl brown WS_3. **$SnCl_2$** yellow; HCl and heat **blue** eoloration. **$BaCl_2$**, white. **$AgNO_3$** white. HCl + Zn, blue eoloration from reduetion. **H_2WO_4** is lemon-eolored, insoluble in water.]

[**Molybdates** of alkalies soluble. Colorless. **HCl** white MoO_3, **soluble** in exeess of HCl, of HNO_3 and of H_2SO_4. Alkaline salts, yellow eolor by H_2S, and pree. brown-blaek by aeids, MoS_3, soluble in $(NH_4)_2S_2$. In **HCl** solution with **Zn** or **Sn**, blue, green, black. Solution of **molybdate of ammonium** dissolved in **HNO_3**, gives **yellow** preeipitate in neutral or acid phosphates: a **test for phosphates.**]

XV. **Borates.** Boraeic acid $B(OH)_3$, and "borax" $Na_2B_4O_7$, $10H_2O$, the eommonest. **Salts** of alkalies, soluble, eolorless, alkaline, fusible. All borates somewhat soluble; easily in acids, and ammonium salts. **HCl** in eoneentrated sols. white,

crystalline $B(OH)_3$, readily soluble in excess or in water. $BaCl_2$ white, soluble in acids. $CaCl_2$ white, sol. in acetic acid or NH_4Cl. Moistened with HCl or H_2SO_4 on platinum, green color to flame. $B(OH)_3$, fuses, gives green color to flame. Turmeric browned. In the case of a borate, add HCl, then turmeric paper; on drying, the latter red-brown, and the red stain blued by soda.

XVI. Chromates of alkalies soluble; yellow or yellow-red. $K_2Cr_2O_7$ reddens litmus. Na_2CO_3 with effervescence, acid to yellow neutral chromate, without precipitation. HCl, deepens the color to red. H_2SO_4 needles of CrO_3, crimson, in concentrated solutions. HCl, heated, evolves Cl_2 and reduces. $HCl + H_2S$, to blue-green Cr_2Cl_6 with deposit of S. (See H_2S.) $AgNO_3$, crimson Ag_2CrO_4, soluble in ammonia and in nitric acid. $Pb_2C_2H_3O_2$, yellow $PbCrO_4$, soluble in KOH. $BaCl_2$ yellow $BaCrO_4$. $CaCl_2$ no reaction. Bi_3NO_3 orange-yellow $Bi_2{}_3CrO_4$.

XVII. Arsenites (p. 14). Alkaline alone soluble; turn red litmus blue. HCl in conc. sols. white As_2O_3, sol. in excess, and precipitated by H_2S as yellow As_2S_3. $CuSO_4$ green $CuHAsO_3$, sol. with blue color in NH_3. $AgNO_3$, yellow Ag_3AsO_3, very soluble in NH_3 and in HNO_3 and in ammoniacal salts. (Dr. Alfred S. Taylor's method of distilling insoluble arsenical compounds with strong HCl is turned to good account with Scheele's Green: the distillate contains $AsCl_3$, precipitable as yellow As_2S_3 by H_2S.)

[Sulpharsenites. K_3AsS_3, alkaline, yellow. With HCl gives H_2S and yellow As_2S_3.]

XVIII. Arsenates (p. 15). $Na_2HAsO_4{,}12H_2O$, chief soluble salt. Soluble alkaline or acid; colorless. HCl no visible reaction. $HCl + H_2S$ no reaction till evaporated nearly to dryness: then H_2S yellow $As_2S_3 + S_2$ soluble in NH_4OH. $AgNO_3$ liver-brown Ag_3AsO_4. $CuSO_4$ in arsenates, greenish-blue $CuHAsO_4$: no pr. in free acid. $BaCl_2$ white $BaHAsO_4$. $MgSO_4$ with NH_4OH in presence of ammoniacal salts, white, crystalline $NH_4MgPO_4{,}6H_2O$. (Some arsenates, such as ferric arsenate, give no distinct mirror with Na_2CO_3 and charcoal.) Reinsch's test and Marsh's test apply to As_2O_3 and As_2O_5.

[Sulpharsenates. K_3AsS_4, colorless, alkaline. HCl gives H_2S and yellow As_2S_5.]

[Antimonites, as $KSbO_2$, give white pr. with HCl soluble in excess. $HCl + H_2S$, orange Sb_2S_3, soluble in HCl as $SbCl_3$. Thus: $Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S$.]

[Antimonates. $K_2H_2Sb_2O_7$ with HCl, white $H_4Sb_2O_7$. With sodium salts $K_2H_2Sb_2O_7$ gives white $Na_2H_2Sb_2O_7$, the only insoluble sodium salt. $HCl + H_2S$ orange Sb_2S_5.]

XIX. Urates. Only alkaline urates soluble. Colorless.

Blue restored to red litmus. **HCl**, white crystalline uric acid $C_5H_4N_4O_3$, insoluble in water, sol. in boiling H_2SO_4. HNO_3 in drops, evaporated to dryness in porcelain basin, gives **yellow-red** residue, turned **purple** by NH_3 (murexid). On **platinum**, carbonizes without flame, and leaves no residue: CNH among the products. Urates leave carbonates when ignited. Ammonium urate evolves NH_3 when heated with Na_2CO_3. Lithium urate, the most soluble. Acid urates, least.

XX. **Hippurates.** Colorless. Alkaline. **HCl**, white **needles** of **hippuric acid**, requiring 600 parts of cold water for solution, but easily soluble in boiling water. $CaCl_2$ in hippurates no precipitate, as calcium salt is soluble. $AgNO_3$, white, soluble in NH_3. Fe_2Cl_6 cream-colored pr. HIPPURIC ACID $CH_2.NH.C_7H_5O.COOH$, leaves a coaly residue, completely consumed in oxydizing flame; evolves CNH among other products. Boiled with acids, assimilates H_2O, and changed into GLYCOCINE CH_2NH_2COOH, and BENZOIC ACID C_6H_5COOH. Heated with KOH gives off benzene C_6H_6 and NH_3.

XXI. **Gallates.** Colorless; alkaline to test-paper. **HCl** minute white crystals, readily soluble in excess of acid. Fe_2Cl_6 **black**, disappearing by heat. $AgNO_3$ white; blackens by heat. Does not precipitate gelatin. GALLIC ACID $C_6H_2(OH)_3COOH$ soluble in 100 of cold, and 3 of boiling water. Acid reaction: decomposes Na_2CO_3 with effervescence. Magenta color with H_2SO_4. Very soluble in ether. **On platinum** blackens instantly.

XXII. **Tannates**, alkaline soluble. Ba, Sr, and Ca tannates, sparingly soluble. **HCl** no visible reaction, as TANNIN $C_{14}H_{10}O_9$ very soluble in water. Fe_2Cl_6, **blue-black** precipitate. $Pb_2C_7H_3O_2$ white. **Gelatin**, white tannate. Turns dark brown with H_2SO_4. On **platinum** fuses and blackens.

XXIII. **Benzoates**, all more or less **soluble**. **HCl** precipitates Benzoic acid in scales, requiring 200 of cold and 25 of boiling water. Fe_2Cl_6 bulky, **flesh-colored**, ferric benzoate, decomposed by **HCl** leaving scales of benzoic acid in the yellow Fe_2Cl_6. $AgNO_3$, white, sparingly soluble. BENZOIC ACID C_6H_5COOH melts at 120°; its vapors are very acrid and irritating, and burn away with sooty flame. Is easily sublimed.

XXIV. **Salicylates**, more or less soluble. **HCl** precipitates salicylic acid in tiny white needles, soluble in excess. Fe_2Cl_6 imparts a **deep-violet** to acid and salts, disappearing with HCl. SALICYLIC ACID $C_6H_4(OH)COOH$ requires 1800 parts of cold water for solution; is readily soluble in alcohol and in oil of vitriol. Melts at 155°: into CO_2 and PHENOL C_6H_5OH.

XXV. **Tartrates.** In sols. of $K_2C_4H_4O_6$ and of $(NH_4)_2C_4H_4O_6$, **HCl** precipitates white crystalline $KHC_4H_4O_6$ and $NH_4HC_4H_4O_6$ soluble in excess. See Group C.

B. Acids, the radicles of which are precipitated by barium chloride or barium nitrate, insoluble in hydrochloric or nitric acids. Includes sulphates, selenates and silicofluorides.

XXVI. **Sulphates**: all soluble except $BaSO_4$, $SrSO_4$ and $PbSO_4$: $CaSO_4,2H_2O$ with difficulty. Neutral or acid to test-paper. $BaCl_2$ white $BaSO_4$, insoluble in **HCl** and in HNO_3. $CaCl_2$ white $CaSO_4,2H_2O$, except in $CaSO_4$ or very weak solutions of other sulphates. $Pb2C_2H_3O_2$, white $PbSO_4$. Any insoluble sulphate on charcoal with Na_2CO_3, fused, gives a sulphide causing a brown-black stain of Ag_2S, when moistened, on a clean silver coin. **Free sulphuric acid** $SO_2(OH)_2$ or H_2SO_4, oily liquid, volatile with white pungent fumes: heats with water. Effervesces with carbonates. Behaves like any other sulphate towards tests. On evaporation, even quite dilute, chars filter-paper when heated.

[**Selenates**, resemble sulphates. $BaCl_2$, white $BaSeO_4$ insoluble in **HCl**; boiled, evolves Cl_2, and then H_2SO_3 separates red Selenium. The original solution, in blowpipe-flame, gives odor of horse-radish.]

XXVII. **Silico-fluorides**. SILICO-FLUORIC ACID $2HF,SiF_4$, acid. $2KF,SiF_4$ and BaF_2,SiF_4, with difficulty in water, insoluble in alcohol. The rest soluble. $BaCl_2$, translucent BaF_2, SiF_4. **KCl** pr. $2KF.SiF_4$. NH_4OH separates H_4SiO_4. On **Platinum**, volatilizes: into $2HF + SiF_4$, therefore etches a glass vessel. Salts heated with H_2SO_4, corrode glass.

C. Acids, the salts of which are precipitated by calcium chloride, soluble in nitric or hydrochloric acids. In addition to I. CARBONATES, III. SULPHITES, IX. FERROCYANIDES, XV. BORATES, XVIII. ARSENATES, XXVI. SULPHURIC ACID and SULPHATES, are the following:

XIII. **Oxalates**. Many insoluble, but soluble in HCl or in HNO_3. **HCl** separates $C_2O_2(OH)_2$ in solution: no visible reaction. $BaCl_2$ white BaC_2O_4, sol. in HCl. $CaCl_2$, white CaC_2O_4, sol. in HCl, **insoluble in acetic acid**. $AgNO_3$ white $Ag_2C_2O_4$, sol. in HNO_3 and in NH_3. **Even $CaSO_4$ precipitates oxalic acid** and oxalates, **insoluble in $CH_3.COOH$**. On **platinum**, into carbonates, oxides or metal, without blackening. OXALIC ACID $H_2C_2O_4,2H_2O$, very soluble in water, very acid. Na_2CO_3 effervescence. **Lime-water** (and the other tests) an immediate white pr. of CaC_2O_4, by heat into $CaCO_3$ without blackening. H_2SO_4 and heat into H_2O, CO_2 and CO, kindling with blue flame, and without darkening. On **Platinum**, fuses and decomposes without blackening; vapors white, coruscating, suffocating.

XXV. **Tartrates**. Neutral tartrates of alkalies readily soluble. $KHC_4H_4O_6$ and $NH_4HC_4H_4O_6$ with difficulty soluble. **HCl** from $K_2C_4H_4O_6$ and $(NH_4)_2C_4H_4O_6$, white crystalline

acid salts readily soluble. **HCl** white pr. in sols. of tartar emetic, sol. in excess and not precipitated by water: H_2S distinguishes Sb. **$BaCl_2$** white. **$CaCl_2$** white $CaC_4H_4O_6$, soluble, when washed, in **KOH** and in **NH_4Cl**; and soluble in **CH_3COOH**. **$AgNO_3$** white, sol. in HNO_3 and in NH_3, reduced to silver by heat. Heated on **platinum**, they carbonize, with smell as of burnt sugar: leave carbonates, oxides or metal. Tartar emetic makes holes in Pt through alloy-formation. TARTARIC ACID $H_2C_4H_4O_6$, very acid. **Na_2CO_3** effervescence. Lime-water precipitates it when added in quantity, sol. in acetic acid. **H_2SO_4** heated with it, browns at once, with little evolution of CO. $Pb_2C_2H_3O_2$, white. On **Platinum** fuses, colors, carbonizes with flame and burnt-sugar smell, leaving no residue.

XXVIII. **Citrates.** Not precipitated by $CH_3.COOK$. **$CaCl_2$ an immediate prec. on heating**, insoluble in KOH when washed, but sol. in NH_4Cl. **Lime-water**, in excess, on **boiling**, a slight white pr. disappearing on cooling. **$AgNO_3$** white $Ag_3C_6H_5O_7$, sol. in NH_3 and HNO_3, not blackening on heating. **Citric acid** $H_3C_6H_5O_7$, very soluble, and acid. **Na_2CO_3**, effervescence. **$CaCl_2$** no prec. even after addition of NH_3, until heated. **H_2SO_4**, and heat, evolves **at first CO** in quantity, burning with blue flame, and only darkening at last. $Pb_2C_2H_3O_2$, white $Pb_3C_6H_5O_7$, sol. after washing, in NH_4OH. On **Platinum**, fuses, carbonizes, with evolution of pungent acid vapors, and burns away.

XXIX. **Malates**: not precipitated by $CH_3.COOK$. **$CaCl_2$, on heating a white pr. in conc. solutions.** **Lime-water** no reaction. **$AgNO_3$** white $Ag_2C_4H_4O_5$, only gray on boiling. **Malic acid** $H_2C_4H_4O_5$, very acid, indistinctly crystalline, resembling glucose in appearance. **Na_2CO_3** effervescence. $Pb_2C_2H_3O_2$, white, cryst. **$CaCl_2$** no reaction. **H_2SO_4**, heated gives CO and CO_2, browning and blackening like Tartaric acid. On **Platinum**, fuses, pungent acid vapors with frothing effervescence; burns away.

XXX. **Meconates.** Colorless. **$CaCl_2$** white. **Fe_2Cl_6**, blood-red coloration, see Group D.

XXXI. **Orthophosphates**: of alkalies soluble. Chief salts:— $Na_2HPO_4,12H_2O$, and $NaNH_4HPO_4,4H_2O$. **HCl** no visible reaction. **HCl + H_2S**, none (not an arsenite). **$BaCl_2$** white, sol. in HCl or HNO_3. **$CaCl_2$** white $Ca_3(PO_4)_2$ **soluble in CH_3COOH.** **Fe_2Cl_6**, white $FePO_4$. $Pb_2C_2H_3O_2$, white. **$NH_4Cl + NH_4OH +$ $MgSO_4$**, white, cryst. $NH_4MgPO_4,6H_2O$. **Ammonium molybdate in nitric acid yellow** pr. containing 3 per cent. P_2O_5. **$AgNO_3$**, **yellow** Ag_3PO_4, sol. in NH_4OH and in HNO_3. On **Platinum**, fuse: into metaphosphates or pyrophosphates which give white $AgPO_3$ and $Ag_4P_2O_7$. ORTHOPHOSPHORIC ACID H_3PO_4, sour, syrupy liquid, into clear glass HPO_3 on heating.

[**Metaphosphates**, by boiling with acids into orthophosphoric acid. In presence of acetic acid, **HPO_3** precipitates albumen.

$AgNO_3$ white gelatinous $AgPO_3$. Not precipitated by magnesium-test.]

[Pyro-phosphates, by boiling with mineral acids into ortho-phosphoric acid. $AgNO_3$, white $Ag_4P_2O_7$, soluble in NH_4OH and in HNO_3.]

[Phosphites of alkaline metals soluble; others with difficulty. $BaCl_2$ white. $CaCl_2$ white, soluble in CH_3COOH. $AgNO_3$. metallic silver. $Hg_2{}^2NO_3$, metallic Hg. H_2SO_3, changes $P(OH)_3$ into H_3PO_4, S being separated. PHOSPHOROUS ACID $P(OH)_3$ by heat into $PH_3 + H_3PO_4$.]

XXXII. **Fluorides.** Alkaline soluble. $BaCl_2$, white. $CaCl_2$ gelatinous, white CaF_2, nearly insoluble in HCl and in acetic acid. AgF is soluble. With H_2SO_4 and heat, pungent HF evolved which corrodes glass.

D. **Acids, the presence of which is demonstrable by the Group-test Ferric chloride.**

a. In presence of **free HCl.** FERROCYANIDES: blue precipitate.

b. In neutral solutions, or if acid on addition of sodium acetate, as the **precipitate** *is occasioned* **even** *in presence of* **free acetic acid.** *Includes:* ARSENATES, GALLATES and PHOSPHATES.

c. Only in neutral solutions. Includes: BORATES, BENZOATES, and SUCCINATES.

XV. **Borates,** see above.

XXIII. **Benzoates,** for the most part soluble. **HCl** white crystalline scales of BENZOIC ACID. Fe_2Cl_6 bulky, flesh-colored ferric benzoate, decomposed by **HCl** with separation of benzoic acid (p. 34).

XXXIII. **Succinates.** Mostly soluble. **HCl** no visible reaction, as succinic acid is readily soluble in water, alcohol and ether. Fe_2Cl_6, pale cinnamon-colored ferric succinate, readily soluble in **HCl**. $Pb_2C_2H_3O_2$ white $PbC_4H_4O_4$, readily sol. in excess of test. $BaCl_2$ and NH_4OH no precipitate until alcohol added. $AgNO_3$, white. SUCCINIC ACID $C_2H_4(COOH)_2$ in colorless, inodorous prisms, readily soluble Volatile: can be sublimed. On **Platinum** burns with sootless flame. Succinates by heat into carbonates (blackening) or oxides or metal.

d. Only coloration in presence of HCl. Includes: X. FERRICYANIDES and XI SULPHOCYANIDES (see above).

e. The red or black coloration disappears on addition of HCl. Includes: XII. ACETATES, FORMATES, XXII. TANNATES, XXXIII. MECONATES, and III. SULPHITES.

XII. **Acetates,** all more or less soluble. **Calcium** and **ferric** acetates very soluble: not precipitated by $CaCl_2$ or Fe_2Cl_6. **HCl** separates $CH_3.COOH$ in solution. Fe_2Cl_6 dark-red coloration, yellow on addition of **HCl**. $AgNO_3$ crystalline, greasy-

looking precipitate, soluble in hot water. $Hg_2{}^2NO_3$, similar pr., readily soluble in the test. H_2SO_4 evolves ACETIC ACID $CH_3.COOH$, known by its pungent odor: mixed with alcohol and heated, agreeable-smelling ETHYL ACETATE $CH_3.COOC_2H_5$ is formed. On **Platinum**, into carbonates, somewhat carbonaceous, oxides or metal. ACETIC ACID is pungent, acid, very volatile, liquid, leaving no residue. NH_4OH must be added to obtain proper reaction with Fe_2Cl_6.

[**Formates** are all soluble. Fe_2Cl_6, similar to acetates. **H.COOAg** and $(H.COO)_2Hg_2$, readily reduced to metallic state by heat.]

XXII. **Tannates**, see above. Gelatin precipitates tannin.

XXXIII. **Meconates**: already mentioned. Alkaline meconates readily soluble. $CaCl_2$ white meconate: by **HCl** crystalline scales of MECONIC ACID $H_3C_7HO_7,3H_2O$. Fe_2Cl_6 **blood-red coloration, not bleached** by $HgCl_2$, nor by $AuCl_3$, but by **HCl**. $Pb_2C_2H_3O_2$ white (none with an acetate). $AgNO_3$, white, sol. in NH_3 and in HNO_3. On **Platinum**, meconic acid loses water, melts, inflames, leaving coaly residue which burns away.

E. **Acids, salts of which, or the radicles of which, are precipitated by silver nitrate.**

a. In neutral solutions only, and the precipitate is readily soluble in dilute nitric acid. Includes: PYRO- and META-PHOSPHATES, BORATES, OXALATES, &c., **white**; ARSENITES, **yellow** and ORTHOPHOSPHATES, **yellow**; ARSENATES, **liver-brown**; CHROMATES, **crimson**, &c.

b. The precipitate is insoluble in dilute nitric acid. Besides SULPHIDES, **black**; FERRICYANIDES, **red-brown**; SULPHOCYANIDES, CYANIDES, FERROCYANIDES, IODATES, **white**, we include **chlorides, bromides, iodides.**

XXXIV. **Chlorides**: all soluble except AgCl and Hg_2Cl_2; with difficulty $PbCl_2$ and TlCl. Generally colorless. Neutral or acid to test-paper. Many volatile. $AgNO_3$, **white, curd-like, fusible AgCl: soluble in NH_4OH**, and to some extent in strong mineral acids, from which it is **re-precipitated by water.** $Hg_2{}^2NO_3$, white Hg_2Cl_2, by NH_3 into **black** Hg_2H_2NCl. $Pb_2C_2H_3O_2$, white $PbCl_2$, except in dilute solutions. Heated with $K_2Cr_2O_7$ and H_2SO_4, blood-red drops of CrO_2Cl_2 condense from brown-red vapor. HYDROGEN CHLORIDE **HCl** is acid, volatile, suffocating: with HNO_3 it deepens to yellow-red in color, and evolves $Cl_2 + NOCl_2$. Leaves no residue on **Platinum.** Fumes with glass-rod dipped into NH_3. If a trace of a chloride be added to a bead of $NaPO_3$ containing a little CuO, and the bead heated in the reducing flame, **blue flame** will be observed. $MnO_2 + H_2SO_4$ added to a chloride yields Chlorine gas which

bleaches, and separates Br and I respectively from alkaline bromides and iodides.

XXXV. **Bromides**: very closely resemble chlorides. $AgNO_3$, yellowish-white **AgBr, sparingly soluble in NH_3**, and insoluble in dilute HNO_3. $Pb_2C_2H_3O_2$, white $PbBr_2$, less soluble than $PbCl_2$. $Hg_2{}^2NO_3$ yellowish-white Hg_2Br_2. Cl_2 water colors a soluble bromide yellow or yellow-red from Br_2, which is soluble with orange-color in $CHCl_3$: starch is colored orange. HNO_3 separates Br_2, with red-brown vapor condensing to blood-red drops. HYDROGEN BROMIDE **HBr** is acid, colorless, completely volatile without residue. Cl_2 sets Br_2 free. $AgNO_3$ yellowish-white **AgBr**, insoluble in dilute HNO_3. HNO_3 separates Br_2. AgCl decomposed by KBr into **AgBr** + KCl.

XXXVI. **Iodides**: many iodides insoluble. $AgNO_3$, whitish-yellow AgI, insoluble in NH_4OH and in HNO_3. $Pb_2C_2H_3O_2$ yellow PbI_2, sol. in much water. $HgCl_2$ scarlet HgI_2. $Hg_2{}^2NO_3$, finch-green Hg_2I_2. Mixed $CuSO_4 + FeSO_4$, white Cu_2I_2. Cl_2 water separates **brown I_2**, soluble in $CHCl_3$ to amethystine color. HNO_3 containing HNO_2 precipitates blue-black iodine, the vapor of which is violet, and forms blue iodide with starch. $MnO_2 + H_2SO_4$ liberates I_2. Bead of $NaPO_3$ saturated with CuO, heated on Platinum-wire with an iodide, imparts *green* color to reducing flame. HYDROGEN IODIDE HI, browns rapidly from separation of I_2, acid, volatile without residue. Cl_2 separates I_2. Free I_2 discoverable by shaking up with $CHCl_3$.

Any insoluble chloride, bromide, or iodide fused with Na_2CO_3, will contain respectively NaCl, NaBr, NaI in a soluble form. **AgCl** is decomposed by KI into **AgI** + KCl.

F. Acids, the salts of which are all soluble in water, and are therefore not precipitated by reagents. Includes: **chlorates and nitrates**, and [PERCHLORATES].

Chlorates (VI.) have been described at p. 30. **HCl** produces green-yellow euchlorine $Cl_2O_4 + 3Cl_2$, especially when heated. H_2SO_4 evolves Cl_2O_4 as greenish-yellow gas: sulphindigotic acid then decolorized. If a chloride present, Ag_2SO_4 can be added to remove Chlorine.

XXXVII. **Nitrates**: all soluble, except $Bi_2O_3{,}2HNO_3$. **HCl** concentrated, evolves $NOCl_2$ and Cl_2 which dissolves gold-leaf. Dilute; no reaction. $BaCl_2$ no reaction. $AgNO_3$ no reaction. Add $FeSO_4$ in solution, and then H_2SO_4 more or less freely. A dark-brown coloration ($2FeSO_4{,}NO$), at the point of junction, increasing by shaking and then disappearing, solution colored from ferric salt. **Sulphindigotic acid** turned yellow by the acid set free from a nitrate. Copper-turnings, together with H_2SO_4, yield orange vapors of NO_2. On **Platinum**, an alkaline nitrate first into a **nitrite**, and this, dissolved, gives with acetic acid,

KI and starch, blue iodide of starch. FREE NITRIC ACID HNO_3, is colorless and caustic in odor; when fuming, yellow from HNO_2. Strongly acid, volatile; leaves no residue. **HCl** produces more or less of a yellow or orange color, with fumes of chloro-nitric gas $NOCl_2$ and of Cl_2, dissolving Au as $AuCl_3$, bleaching litmus and indigo-solution. Na_2CO_3 effervescence. **Stains wool yellow.** $FeSO_4$ browns: **on heating,** if dilute. **Cu** when heated gives $2NO + O_2 = 2NO_2$ as orange-red vapors. If dilute, neutralize with $CaCO_3$, filter, evaporate to dryness and decompose with H_2SO_4 containing solution of ferrous sulphate.

[**Perchlorates.** **HCl** added, indigo-solution not bleached. Evolve O on heating, and changed into chlorides: **KCl** in concentrated sols. pr. $KClO_4$.]

RECAPITULATION.

Salts of organic acids, except oxalates, acetates, and formates, are **charred** when heated. In presence of **HCl**, soluble carbonates, sulphides, hyposulphites, nitrites, ferrocyanides, benzoates, hippurates and urates, chlorates, hypochlorites, and silicates are at once recognizable. Even in admixture a carbonate is decomposed before a sulphite is attacked, so that much is learnt by a careful addition of the test. If **HCl** produces **no** reaction, the addition of H_2S settles the presence or otherwise of **chromic acid** (p. 33) of As_2O_3 (p. 14): boiling, concentrating and further addition of H_2S would indicate by **yellow** $As_2S_3 + S_2$, presence of arsenic acid (p. 15). **Barium chloride** $BaCl_2$ precipitates, in addition to the above-named, iodates, bromates, borates, phosphates, oxalates, fluorides, sulphates, silicofluorides, and ferrocyanides; precipitated $BaSO_4$ and BaF_2SiF_4 are insoluble in HCl. **Silver nitrate** precipitates chlorides, bromides, iodides, cyanides, and ferricyanides: chloride of barium does not precipitate them. **Ferric chloride** is also an admirable test. The **red-brown** coloration **disappears** in the case of acetates, meconates, formates, and the **black** coloration in the case of the gallates, **on addition of HCl,** but the **brown** coloration of ferricyanide and the **blood-red** sulphocyanide are not thus bleached. **HCl,** however, in no wise interferes with the FERROCYANIDE reaction. Only in neutral solutions a borate, benzoate and succinate can produce a ferric precipitate, and only in presence of acetic acid, a phosphate, arsenate and tannate.

For further particulars, see the respective acids, the characteristic features of which can be easily mastered by the intelligent student. Except for grouping, **Tables** are not to be recommended unless constructed by the student himself.

II. THE SUBSTANCE IS INSOLUBLE IN WATER (see p. 12). If the substance is insoluble in water, it is boiled with strong **HCl**. The following gases may be evolved: CO_2 from a **carbonate**; H_2S from a **sulphide**; SO_2, from a **sulphite** or **hyposulphite**; **HCN** from a **cyanide**; Cl_2 from a **peroxide** or **chromate** (turns green); I_2 (violet vapor) from an **iodate**; Br_2 (orange) from a **bromate**. Many silicates gelatinize; in such case, evaporate to dryness, ignite gently, and re-dissolve in HCl; SiO_2 remains behind as a white, insoluble powder, **while the bases pass into solution**.

If the main part of the substance has dissolved, filter or decant, boil off any large excess of HCl, dilute with a little water, and proceed with the use of Group-tests as given at pp. 11 and 12. **N.B.** If crystals form in the solution on cooling, e.g. arsenious, boracic, benzoic, hippuric, uric, and gallic acids, lead chloride, barium chloride, calcium, barium, strontium and magnesium phosphates and oxalates,—more water should be added. A **yellow** residue may be **sulphur** or **titanic acid**: an **orange** one, with odor of CNH, a **sulphocyanide**. A turbidity, on dilution, indicates **Sb** or **Bi**. If the solution gives a precipitate with $NH_4Cl + NH_4OH$, a **phosphate** or **oxalate** may be present, as well as Fe_2, Al_2 or Cr_2. In this case, test the original substance as follows: *a*. Heat on platinum foil, treat the **ash** with **HCl**; effervescence indicates **oxalate**; test for the probable basyl Ca, Ba, Sr. *b*. To a solution of ammonium molybdate in HNO_3, add a drop of the HCl solution, and warm,—a **yellow** precipitate indicates a **phosphate**. *c*. To a fresh portion of the HCl solution, add **sodium acetate** in excess: $CrPO_4$, is **green**, $FePO_4$, and $AlPO_4$ are white and gelatinous. Test for **Fe** (p. 19); if absent, nearly neutralize another portion with Na_2CO_3, boil with pure **KOH** and $BaCO_3$ and filter; to the filtrate add HCl in excess, then NH_4OH in excess, and warm,—white gelatinous **aluminum hydroxide** will be precipitated. The barium precipitate on the filter is dissolved in hot dilute **HCl**, H_2SO_4 added to **remove Ba** as $BaSO_4$, the solution boiled, filtered, and tested with NH_4Cl, NH_4OH and $MgSO_4$ for the presence of a **phosphate**, which will be indicated by a white, crystalline deposit of $NH_4MgPO_4,6H_2O$. *d*. If **sodium acetate** has produced a **precipitate**, filter and add to the filtrate NH_4OH: a **precipitate** indicates excess of $Al_2(OH)_6$ $Fe_2(OH)_6$ or $Cr_2(OH)_6$. *e*. If no reaction with sodium acetate, add Fe_2Cl_6 till solution **reddish**,—a **white precipitate** indicates calcium, barium, strontium or magnesium phosphate; boil till liquid colorless, filter, test the filtrate for these metals (pp. 24, 25). If necessary, the ferric precipitate can be tested for **orthophosphoric acid**, by dissolving in warm HCl, adding tartaric acid to prevent the separation of ferric, NH_4OH and then $MgSO_4$ to the clear solution: crystalline $NH_4MgPO_4.6H_2O$ follows, if **phosphate** present. *f*. **Fluorides** and **borates** of **Ba, Sr,**

Ca and **Mg** may also be precipitated by NH_4OH; therefore the original substance must be tested on **Platinum** with H_2SO_4,—a BORATE gives **green** color to flame. **Fluorides** evolve **HF**, which corrodes glass. If either present, add more NH_4Cl and test for **Ba, Sr, Ca** or **Mg**.

If insoluble in HCl, boil with HNO_3. Remove nearly all the free acid by evaporation, and test the solution for the various bases under the different Groups.

If insoluble in HNO_3, boil with aqua regia. Remove free acids, dilute and test. Be careful to remove both HNO_3 and Cl_2, as they decompose H_2S, with deposition of Sulphur.

As regards the **examination for the radicle in substances only soluble in acids**, indications have already been noted (p. 40). All **borates** are soluble in HCl; on **Platinum** with H_2SO_4, all borates give **green** color to flame. In the **HCl** solution, $BaCl_2$ discovers a **sulphate** (p. 35); in any **sulphide**, the action of nitric acid would be to create a sulphate. In the case of **silicates**, evaporate to dryness, ignite and re-dissolve in HCl: **silica** SiO_2, remains undissolved. **Phosphates** are all decomposed by acids; their detection has been explained at pp. 36, 41. In the case of an **organic salt**, blackening with a residue would occur; dissolve the residue in HNO_3, evaporate, re-dissolve in water, precipitate by H_2S or by Na_2CO_3, and in the **filtrate** test for the **base**.

IF A SUBSTANCE IS INSOLUBLE IN WATER AS WELL AS IN ACIDS, various methods must be employed. **Carbon** disappears when strongly ignited, and deflagrates with KNO_3. **AgCl, AgBr** and **AgI** melt when heated, and give metallic **Ag**, heated with Na_2CO_3. Al_2O_3, is white, infusible, is turned **blue**, when ignited with Co_2NO_3: unlocked by fusion with $KHSO_4$. SnO_2 and Sb_2O_5 give ductile or brittle metallic beads respectively of Sn or Sb when heated on **charcoal** with Na_2CO_3. In a platinum capsule they may be reduced by Zn + HCl; **Sb** will stain the Pt black. They may also be unlocked by fusion with Na_2CO_3. **Silica** and certain **silicates** are untouched by acids; heated in the sodium metaphosphate bead they yield a skeleton of SiO_2. They can be unlocked by HF; or by fusion with $Ba(OH)_2$; or with 3 times their weight of Na_2CO_3, treatment with HCl, evaporation to dryness, moistening with HCl, and addition of water which leaves SiO_2 undissolved. If **K** or **Na** to be sought for, then $Ba(OH)_2$ **must** be used. **Fluorides** are white: all evolve **HF** when heated with H_2SO_4, and corrode a watch-glass placed over the platinum-capsule. **Chromic oxide** gives a **green** bead with borax. It is best unlocked with a mixture of Na_2CO_3 and KNO_3, yielding soluble yellow chromate. Some **alloys** are best heated

in an atmosphere of chlorine, after admixture with sodium chloride.

LIST OF SUBSTANCES, ONE OR OTHER OF WHICH IS GIVEN FOR ANALYSIS AT THE FIRST M.B. EXAMINATION OF THE UNIVERSITY OF LONDON.

A. **Alcohol, urea, sucrose, dextrose, starch** and **glycerin.** B. The alkaloids **morphin, strychnin, quinin** and **cinchonin.** C. **Oxalic, tartaric, citric, malic** and **uric acids.** D. **Succinic, benzoic** and **hippuric acids.** E. **Acetic acid.** F. **Meconic, tannic** and **gallic acids.** G. **Sulphocyanides, ferrocyanides** and **ferricyanides.** H. **Cyanides.**

General remarks. Alcohol, urea, sucrose, dextrose, starch and glycerin are neutral or only very faintly acid to test-paper.

All the **free acids,** viz. oxalic, tartaric, citric, malic, succinic, benzoic, hippuric, acetic, meconic, tannic and gallic acids, occasion effervescence with **sodium carbonate,** which last is recommended to be used after application of test-paper. If there is no effervescence, the above-mentioned acids may be passed over. If there is no precipitate, either immediate or after continuous stirring, the absence of most bases (including the alkaloids morphin, strychnin, quinin and cinchonin) may be inferred, excepting ferric, potassium, sodium and ammonium (L, Cs and Rb). The only acids leaving no solid residue are **acetic** and **hydrocyanic acids,** but the former occasions effervescence with Na_2CO_3: both are surely recognizable by the smell, and, the latter, by **silver nitrate,** which precipitates silver cyanide. Uric acid is so nearly insoluble in water, that, except solid, or in the form of a strongly alkaline solution of urate of potassium, sodium or ammonium, it need not be thought of.

An alkaline solution should be tested with Na_2CO_3: basic lead acetate would be precipitated, and any other metallic salt, the carbonate of which is insoluble in water. Heat should always be applied to make sure of the absence of a salt of ammonium. On application of gentle heat, a solution of tartar emetic is precipitated. A solution of a urate, or of potassium cyanide, would be strongly alkaline and unaffected by Na_2CO_3; so also would be an alkaline hippurate, gallate, tannate and possibly other organic salts. **Hydrochloric acid,** *carefully added,* is the next most important test, as it not only precipitates $PbCl_2$ from $Pb_2C_2H_3O_2$, and basic antimonous chloride from tartar emetic, readily soluble in excess, but it precipitates URIC ACID (as a powder), HIPPURIC ACID (in needles), BENZOIC ACID (in scales), GALLIC ACID (easily soluble), FERROCYANIC ACID (bluish white) from a **yellow** solution, and potassium hydrogen tartrate from neutral TARTRATE, as a white crystalline powder (readily soluble).

Hydrogen sulphide may be added to any precipitate with HCl, and any doubt as to the metallic character or otherwise confirmed. **Ferric chloride** gives most important reactions. With GALLIC and TANNIC ACIDS a blue-black coloration or precipitate, bleached by HCl: gelatin precipitates tannin alone. With neutral salt of MORPHIN, a dark blue color: orange with HNO_3. With SULPHOCYANIDES, intense blood-red color, not bleached by HCl, but by $HgCl_2$. With ACETATES, **deep red-brown** color, bleached by HCl: the original salt with alcohol and sulphuric acid yields ethyl acetate. With MECONATES, an intense **port-wine** color, not bleached by $HgCl_2$ or by $AuCl_3$ but by HCl. With FERROCYANIDES, **Prussian blue**, not altered by HCl With FERRICYANIDES, **brown** color, not bleached by HCl (with a ferrous salt, **Turnbull's blue**). With benzoic, hippuric and succinic acids no reaction, but with BENZOATES, HIPPURATES and SUCCINATES, respectively, a flesh-colored, a brown, and a red-brown precipitate: on addition of **HCl**, scales of **benzoic acid**, needles of **hippuric acid** and no separation of **succinic acid**. No precipitation with OXALATES, TARTRATES, CITRATES and MALATES, and no change of color, beyond what springs from dilution of the ferric chloride. **Calcium chloride** is also a Group-test. Succinate, benzoate, hippurate, and acetate of calcium, are sufficiently soluble in water to allow of the detection of the radicles with ease: in soluble salts of these radicles, of course $CaCl_2$ will produce no visible results. **Oxalate of calcium** is so insoluble, that even lime-water produces an **immediate** precipitate in soluble oxalates, insoluble in acetic acid. **Tartrate of calcium** is so little soluble in water, that lime-water **in excess** precipitates tartaric acid, but the precipitate is soluble in acetic acid. **Of course $CaCl_2$**, precipitates both an **oxalate** and a **tartrate**. Lime-water, in excess, has no effect upon CITRIC ACID, until boiled, when **calcium citrate** is precipitated. Under **no** circumstances, however, could lime-water precipitate a soluble malate or **malic acid**. For the distinctive tests see pp. 48, 49.

In addition to the tests here enumerated, the effects of heat are to be particularly studied. Thus, the ALKALOIDS fuse, and burn like resins, with a beautiful, sooty flame. They are practically insoluble in water, although their solution blues red litmus paper. As salts, morphin, strychnin, quinin and cinchonin are precipitated by **sodium carbonate**. **Nitric acid** in excess will distinguish **morphin**: **sulphuric acid** added to the solid alkaloid or salt, together with MnO_2, or PbO_2, or $K_2Cr_2O_7$, will, by the **purple** color, decide for **strychnin**: **chlorine water** and **ammonia**, by the **green** color, settle the presence of **quinin**. Solutions of salts of **cinchonin** are not fluorescent, are **not** turned **green** by $Cl_2 + NH_4OH$, and the precipitate effected by NH_4OH is not soluble in ether, as is quinin when similarly treated.

The use of **argentum nitrate** has been already commended at pp. 1, 10. Silver **oxalate** is white and soluble in dilute nitric acid: silver **cyanide, ferrocyanide** and **sulphocyanide** are also white, but insoluble in dilute nitric acid. Silver **ferricyanide** is red-brown and insoluble in dilute nitric acid. **The distinctive tests for the various substances are as follows:—**

GROUP A includes ALCOHOL, UREA, SUCROSE, GLUCOSE, STARCH, and GLYCERIN.

Alcohol ethylic $CH_3.CH_2OH$. **Colorless** liquid of purely spirituous odor, **neutral** to test-paper, leaving **no residue** on **platinum**. Unless very weak, it is **inflammable**, burning with pale-bluish flame. $K_2Cr_2O_7 + H_2SO_4$, **reduced to blue-green or green** salt of chromic oxide. Heated with H_2SO_4 and CH_3COOH, alcohol yields $CH_3.COOC_2H_5$.

Urea $CO(NH_2)_2$, in solution, is **colorless and inodorous. Neutral** to test-paper. Carefully evaporated, a solid crystalline residue is left, easily fusible, emitting ammoniacal odors, discoverable by red litmus paper: it **solidifies** soon after fusion, as white **cyanuric acid** $Cy_3(OH)_3$, which **entirely volatilizes without blackening.** Na_2CO_3 no precipitation, as urea is so very soluble. HNO_3 in large excess, white crystalline $CO(NH_2)_2$, HNO_3, readily soluble in water. $C_2O_2(OH)_2$, behaves similarly.

Urea in colorless, four-sided prisms, very sol. in water and in alcohol. Neutral. Fuses to clear liquid: evolves NH_3 and $CNONH_4$, solidifies and volatilizes as CNOH without blackening. Na_2CO_3 no reaction on its solution in water. HNO_3 precipitates white $CO(NH_2)_2.HNO_3$. Instantly decomposed by $2HNO_2$ into: $CO_2 + 2N_2 + 3H_2O$. Salts of urea are acid; effervesce with Na_2CO_3, but afford no precipitate.

Sucrose $C_{12}H_{22}O_{11}$, in solution, is colorless and inodorous. **Neutral** to test-paper. On evaporation becomes syrupy, then yellow, deepens in color, intumesces, inflames, evolves smell of burnt sugar as it blackens, gives coaly residue which burns away. Na_2CO_3 no reaction. $CuSO_4 + KOH$, the latter till deep-blue solution, no precipitate if heated till near boiling. H_2SO_4 in excess, gives mass of carbon. **KOH** no distinctive reaction.

Sucrose $C_{12}H_{22}O_{11}$, in colorless, transparent, four-sided, oblique-rhombic prisms, very soluble in water, forming a thick syrup. Melts to glassy mass. Heated to 160° into GLUCOSE $C_6H_{12}O_6$, and LAEVULOSAN $C_6H_{10}O_5$; at 210° into caramel $C_{12}H_{18}O_9$; then, with evolution of inflammable gases into carbonaceous mass which burns away. H_2SO_4 into **carbonaceous matter.** Does **not** at once reduce **cupric hydrate,** when blue solution of cupric hydrate with sucrose in KOH is boiled: but, when solution of sucrose is heated with dilute acids, it is changed into dextrose, p. 46.

Glucose $C_6H_{12}O_6$, in solution, is colorless, or yellow-tinted; neutral or faintly acid. Na_2CO_3 no reaction. On Platinum behaves like sucrose. $CuSO_4$ and **KOH** in excess, a deep-blue solution from which **yellow** cuprous hydroxide, and then red **cuprous oxide** is precipitated, even **before liquid boils.** **KOH** on heating, a rich mahogany color. H_2SO_4 converts glucose into SULPHO-SACCHARIC ACID $C_6H_{12}O_5SO_3$.

DEXTROSE or GLUCOSE $C_6H_{12}O_6,H_2O$, dissolves in 1.23 parts of water, and is less sweet than sucrose. It is soluble in alcohol. At 170° into glucosan $C_6H_{10}O_5$. It dissolves BaO, CaO and PbO, and combines also with NaCl.

Starch $C_{18}H_{30}O_{15}$ affords a more or less gelatinous liquid, neutral or faintly acid. Or only opalescent. Evaporated on **Platinum**, a whitish or yellowish residue, burning with yellow flame, leaving first a carbonaceous residue which completely oxydizes. Na_2CO_3, no reaction. **Iodine water**, strikes a **deep-blue color**, disappearing on heating: **the chief test.** Dilute sulphuric changes it into glucose. H_2SO_4 into AMIDIN-SULPHURIC ACID.

STARCH $C_{18}H_{30}O_{15}$, a soft, white, glistening powder, insoluble in cold water. Forms a thick, unmistakable paste when boiled with water, and is at once recognized by solution of iodine.

Glycerin $C_3H_5(OH)_3$, in solution, is more or less viscid. Neutral, or faintly acid. Na_2CO_3 no reaction. On evaporation, more and more viscid, evolving in a test-tube white vapors smelling of red-hot candle-wick. Heated then with $KHSO_4$, **acrolein** of pungent, irritating odor. On **Platinum**, it **burns** with steady white **flame without blackening** and **without residue**, remaining liquid until the end.

GLYCERIN $C_3H_5(OH)_3$, colorless, viscid liquid, of sp. gr. 1.27, boiling at 200° C. Intensely sweet. Readily soluble in water and in alcohol. By loss of $2H_2O$, into ACROLEIN C_3H_4O, most pungent of vapors.

GROUP B. Includes MORPHIN, STRYCHNIN, QUININ and CINCHONIN.

Heated on Platinum they fuse, redden, and burn with bright sooty flame, leaving sooty incrustation which burns away. Very little soluble in water: solutions blue red litmus. Na_2CO_3, with brisk stirring separates the respective alkaloids, more or less rapidly, from solutions of their salts.

Morphin $C_{17}H_{19}NO_3$, only soluble in 1000 of water. Solution of salts neutral or acid. Na_2CO_3, on stirring, white, crystalline precipitate. Fe_2Cl_6, dark blue. HNO_3 gives **deep-orange color,**

oven in solutions of salts. Mixed with HIO_3, iodine is liberated, blues starch, and dissolves with amethystine color in $CHCl_3$. Mixed $HNO_3 + H_2SO_4$, a green coloration.

MORPHIN $C_{17}H_{19}NO_3,H_2O$, in short, rectangular prisms, sol. in 400 boiling water. Soluble in alcohol, but not in ether and chloroform. Soluble in KOH. Turmeric browned. HNO_3, deep-orange. Salts very soluble in water and alcohol: morphin precipitated by Na_2CO_3, and by NH_4OH; stirring generally required.

Strychnin $C_{21}H_{22}N_2O_2$, almost insoluble in water (7000 parts). Solution of salts, neutral, soluble. Na_2CO_3, white, crystalline precipitate. KOH, likewise; needles as seen under microscope. NH_4OH, white, soluble in excess. The dry salt, or alkaloid, with H_2SO_4 in porcelain dish and $K_2Cr_2O_7$, blue-violet color, changing to red and reddish-red. With MnO_2 or with PbO_2, a similar reaction. Chlorine water a white precipitate.

STRYCHNIN $C_{21}H_{22}N_2O_2$, in brilliant rhombic prisms, insoluble in absolute alcohol, ether, and KOH; readily soluble in $CHCl_3$. Its salts, if acid, are not precipitated by $NaHCO_3$. KCNS in solutions, white crystalline tufts.

Quinin $C_{20}H_{22}N_2O_2$, soluble in 350 parts of water. Its salts may be neutral or acid, and reflect a bluish tint. $NaHCO_3$ easily precipitates quinin. KOH and NH_4OH, white, amorphous, readily soluble in ether. Chlorine water and then NH_4OH, an emerald-green color. $Cl + K_4FeCy_6 + NH_4OH$, deep-red tint, changing to dirty-brown.

QUININ $C_{20}H_{22}N_2O_2$, in silky needles, soluble in alcohol and ether. H_2SO_4 dissolves it with slight yellow color. HNO_3, colorless. Salts fluorescent. Turns plane of polarization to the left.

Cinchonin $C_{20}H_{24}N_2O$, is less soluble in water. Salts more soluble in water, and in alcohol, than those of quinin. $NaHCO_3$ white, amorphous. KOH and NH_4OH, white, amorphous cinchonin, insoluble in ether. Chlorine water and then NH_4OH, a yellowish-white precipitate. K_4Cfy white flocculent ferrocyanide, soluble in excess, and, after gentle heat, separating in golden scales or needles.

CINCHONIN $C_{20}H_{24}N_2O$, in large, quadrilateral prisms, less soluble in alcohol than quinin and insoluble in ether. Readily sublimed in hydrogen. Turns plane of polarization to the right. CINCHONIDIN is laevo-gyrate.

GROUP C. Includes OXALIC, TARTARIC, CITRIC and MALIC ACIDS. Heated on Platinum they fuse. Oxalic acid decomposes, without carbonizing, and the fumes are white and very irritating. Tartaric acid carbonizes, and emits smell of burnt sugar. Citric acid also carbonizes, but the fumes are pungent. Malic

acid froths much, and also gives off pungent vapors. They are very soluble in water; neither the acids nor the salts are precipitated by ferric chloride. The calcium salts are either insoluble or with difficulty soluble in water.

Oxalic acid $C_2O_2(OH)_2,2H_2O$. Page 35. Colorless rhombic prisms, soluble in eight parts of water. Strongly reddens litmus. Effervesces with Na_2CO_3. FERRIC CHLORIDE NO REACTION. **Lime-water** an immediate white **precipitate of** CaC_2O_4, insoluble in acetic acid. $CaCl_2$ and $CaSO_4$, white CaC_2O_4, even in acetic acid solution. H_2SO_4, on heating, decomposes it **without darkening** into CO and CO_2, carbonic oxide burning with **blue** flame. $AgNO_3$, white, oxalate. $Pb_2C_2H_3O_2$, white, lead oxalate. **On Platinum,** fuses, and decomposes without carbonizing: fumes white, irritating and cough-provoking. OXALATES into carbonates, or oxides, or metal. Calcium oxalate is "mulberry calculus." By heat into $CaCO_3$, soluble with effervescence in HCl, not precipitated by NH_4OH, nor by $CaSO_4$, but by $C_2O_2(ONH_4)_2$. See p. 24.

Tartaric acid $C_2H_2(OH)_2(COOH)_2 = C_4H_6O_6$. Page 35. Colorless oblique-rhombic prisms, very soluble. Acid reaction. Effervesces with Na_2CO_3. FERRIC CHLORIDE NO REACTION. **Lime-water in excess** a white precipitate, soluble in acetic acid. $CaSO_4$ no precipitate (distinction between oxalic and tartaric acid). $CaCl_2$ no precipitate: but, in tartrates, soluble in ammonium chloride. **KOH,** white, crystalline, cream of tartar, if solution acid to test-paper. NH_4OH, white crystalline ammonium hydrogen tartrate, in acid solution. Test-paper should be inserted in the liquid, and the latter stirred or shaken. H_2SO_4, browning and blackening at once, with evolution of gas. $Pb_2C_2H_3O_2$, white lead tartrate, very soluble in ammonia. $AgNO_3$, no precipitate: but one in tartrates. **On Platinum,** fuses, carbonizes, emits smell of burnt sugar, and residue burns away. **Tartrates** carbonize, evolve smell of burnt sugar. $K_2C_4H_4O_6$ very soluble in water, alkaline. $KHC_4H_4O_6$ acid to test-paper, requiring 160 parts of cold water. By heat into K_2CO_3, with violet color to flame, sol. in HCl with effervescence, not prec. by NH_4OH, nor by Na_2CO_3: with $PtCl_4$ yellow $2KCl,PtCl_4$. TARTAR EMETIC $2(KSbOC_4H_4O_6)H_2O$, is slightly acid, soluble, precipitated by **HCl,** and by Na_2CO_3 **when heated.** $HCl + H_2S$ orange Sb_2S_3, sol. in HCl and also in $(NH_4)_2S_2$. **On Platinum,** violet color to flame, and the reduced antimony forms a fusible alloy with the platinum.

Citric acid $C_3H_4(OH)(COOH)_3 = C_6H_8O_7$. Page 36. Colorless, oblique-rhombic prisms, very soluble. Acid reaction. Effervescence with Na_2CO_3. FERRIC CHLORIDE NO REACTION. **Lime-water,** in excess, no precipitate; but after boiling some time. $CaSO_4$ no precipitate. $CaCl_2$ no precipitate: but on

neutralizing with KOH. Neutralized with NH_4OH, no prec. with $CaCl_2$ until heated. H_2SO_4 readily evolves CO, with but slight change of color. This its behaviour, most like oxalic acid: only on long boiling darkens. $AgNO_3$ no reaction except in citrates: then white pr. $Pb_2C_2H_3O_2$, white, amorphous, freely soluble in ammonia. **On platinum** fuses, carbonizes; fumes pungent. CITRATES, with **carbonization**, into carbonates, or oxides, or metal.

Malic acid $C_2H_3(OH)(COOH)_2 = C_4H_6O_5$. Page 36. Deliquescent, indistinctly crystalline. Very acid. Effervesces with Na_2CO_3. FERRIC CHLORIDE NO REACTION. Lime-water no reaction. $CaSO_4$ no reaction. $CaCl_2$ none, even after saturation with KOH or NH_4OH, **but upon boiling.** H_2SO_4, gases CO and CO_2 evolved, with almost immediate browning and blackening (resembles tartaric acid). $AgNO_3$ no reaction except in malates. $Pb_2C_2H_3O_2$, white malate, somewhat soluble in malic acid, sparingly in ammonia. Heated carefully in a test-tube, by heat into volatile maleic and fumaric acids. **On platinum** fuses, and evolves pungent, acid vapors.

N.B.—In presence of only one of these four acids, lime-water serves to distinguish.

Uric acid $C_5H_4N_4O_3$. Page 33. White powder, insoluble in water. Blackens immediately when heated, with odor of burnt hair. Solution of potassium urate strongly alkaline. HCl white precipitate of uric acid. HNO_3 as a drop, added to a mere trace of uric acid, and evaporated, a red-brown residue, turned purple by ammonia (purpurate of ammonium or murexid). $CaCl_2$ white calcium urate.

GROUP D. Includes SUCCINIC, BENZOIC, and HIPPURIC ACIDS. When heated they volatilize: hippuric acid with decomposition. The fumes of benzoic acid are most irritating. The calcium salts are soluble in water. **Ferric chloride precipitates** SUCCINATES, BENZOATES and HIPPURATES, respectively **brownish-red, flesh-colored,** and **brown.**

Succinic acid $C_2H_4(COOH)_2 = C_4H_6O_4$. Page 37. Colorless, rhombic prisms, very soluble in water and alcohol, volatile when heated, leaving little carbon which burns away. Acid to test-paper. Effervesces with Na_2CO_3. **Ferric chloride no reaction: but in SUCCINATES a brownish-red pr.** of ferric succinate, **soluble in HCl** with yellow color. $CaCl_2$ no reaction: in succinates none till alcohol is added. $Pb_2C_2H_3O_2$, white. $BaCl_2$ no reaction: **but on addition of ammonia and alcohol,** a white pr., and none with a benzoate. **On platinum,** burns with blue, sootless flame. SUCCINATES are decomposed by heat into carbonates and carbon, oxides and carbon, or metal.

Benzoic acid $C_6H_5.COOH = C_7H_6O_2$. Pages 34 and 37. Colorless scales, soluble in 200 of cold and 25 of boiling water. Acid to test-paper. Effervescence with Na_2CO_3. **Ferric chloride** no reaction: but in benzoates a flesh-colored prec. in which the ferric is dissolved by **HCl**, leaving white scales of benzoic acid. **HCl** separates benzoic acid, in scales, from soluble benzoates. $CaCl_2$ no reaction. $Pb_2C_2H_3O_2$ no reaction, but in benzoates. $BaCl_2$ no reaction. On platinum burns with bright sooty flame, with scarcely a residue. Fuses at 120° and sublimes at 145°. Vapors acrid and irritating. Crystals often odorous of gum-benzoin.

Hippuric acid $CH_2NH(C_7H_5O)COOH = C_9H_9NO_3$. Page 34. In rhombic prisms, soluble in 600 parts of cold, and readily in boiling water. Acid reaction. Effervescence with Na_2CO_3. Salts alkaline. **HCl**, a precipitate of hippuric acid, increased by excess. Fe_2Cl_6, brown precipitate; with **HCl** a yellow chloride, leaving prismatic crystals of hippuric acid. $Pb_2C_2H_3O_2$, curdy pr. $AgNO_3$ white pr. Hg_2NO_3 white. On platinum, melts, burns, leaving coaly residue which burns away.

GROUP E. Includes ACETIC, FORMIC, PROPIONIC, LACTIC, and BUTYRIC ACIDS. Only ACETIC ACID required. Volatile, and capable of distillation: calcium salt very soluble in water. On addition of **ferric chloride** a **pale red** color, turning **yellow** when HCl added.

Acetic acid $CH_3COOH = C_2H_4O_2$. Page 37. In scales, at low temperatures. Pungent, penetrating liquid, odorous of "vinegar." Acid to test-paper. Volatile without residue. Effervescence with Na_2CO_3. **Ferric chloride, pale-red color**: in ACETATES **deep red**, yellow by **HCl** (compare sulphocyanide). $AgNO_3$, in acetates, white, nacreous crystals. Hg_2NO_3 in acetates, white, nacreous crystals. H_2SO_4 separates $CH_3.COOH$ from acetates: with alcohol and H_2SO_4, ACETIC ETHER formed. **On platinum**, acetates into carbonates, oxides, or metal.

GROUP F. Includes MECONIC, TANNIC, and GALLIC ACIDS. **Ferric chloride** produces a **blood-red**, a **blue-black** or a **black** color as well in the free acids as the salts, and the color disappears on addition of HCl. They are easily distinguished by tests.

Meconic acid $C_4HO(COOH)_3 = C_7H_4O_7$, page 38. In scales, sparingly soluble. Acid reaction. Effervescence with Na_2CO_3. Fe_2Cl_6 **blood-red color**, not bleached by $HgCl_2$ or by $AuCl_3$, but by HCl. No coloration in presence of free HCl. $CaCl_2$ no reaction, but, in soluble meconates, white pr. of calcium meconate. $Pb_2C_2H_3O_2$ white precipitate.

Tannic acid $C_{14}H_{10}O_9$. Page 34. Yellowish powder, very soluble in water. Reddens litmus. Effervesces with Na_2CO_3.

Sparingly soluble in ether. Fe_2Cl_6 blue-black precipitate, bleached by HCl. Solution precipitates gelatin. On platinum fuses, blackens and burns away.

Gallic acid $C_6H_2(OH)_3COOH = C_7H_6O_5$. Page 34. Delicate, silky needles requiring 100 parts of cold and 3 of boiling water, so that in solid state cannot be mistaken for tannic acid. Reddens litmus. Effervescence with Na_2CO_3. In alkaline gallates, HCl carefully added, will precipitate gallic acid. Soluble in ether. Fe_2Cl_6 black color, bleached by HCl. Solution does not precipitate gelatin. $Pb^2C_2H_3O_2$, white precipitate.

Group G. Includes sulphocyanides, ferrocyanides, and ferricyanides. Only salts, probably of K, or NH_4. Ferric chloride a deep blood-red color in sulphocyanides, a blue precipitate in ferrocyanides, and a brown coloration in ferricyanides, and the colors not removed by HCl.

Sulphocyanides. Page 32. KCSN and NH_4CSN, the chief salts. Colorless solution. Na_2CO_3 no reaction, except in NH_4CSN, when $(NH_4)_2CO_3$ evolved. Fe_2Cl_6, deep blood-red color, not bleached by HCl: but, on addition of a small piece of zinc, bleached and H_2S evolved. Color also bleached by $HgCl_2$. $Pb^2C_2H_3O_2$, white, very soluble in acetic acid and in the salt.

Ferrocyanides. Page 31. $K_4FeCy_6.3H_2O$ the chief salt. Lemon-yellow in color. Na_2CO_3 no reaction. Fe_2Cl_6, Prussian-blue, even in presence of HCl. HCl, bluish-white pr. of H_4Cfy, readily soluble in water. $CuSO_4$, maroon Cu_2Cfy.

Ferricyanides. Page 31. $K_6Fe_2Cy_{12}$, the chief salt. Brownish-green solution. Na_2CO_3 no reaction. Fe_2Cl_6 brown coloration not removed by HCl. HCl no visible reaction. $FeSO_4$, Turnbull's blue.

Group H. Includes cyanides. Alkaline cyanides blue red litmus. $CaCl_2$ no reaction. Fe_2Cl_6 no reaction. $AgNO_3$, white curd-like precipitate, soluble in strong HNO_3 and strong NH_4OH.

Cyanides. Page 31. CNK smells of prussic acid. A watch-glass dotted with silver nitrate, receives opalescent spots of CNAg. HCl more distinctly separates CNH. Na_2CO_3 no reaction. $FeSO_4$, in cyanides, red precipitate. $AgNO_3$, white CNAg, soluble in boiling HNO_3, and in strong NH_4OH. $FeSO_4$ + KOH heated, and HCl added, Prussian-blue remains. Boiled with a little $(NH_4)_2S_2$, evaporated, re-dissolved in much water and ferric chloride added, blood-red ferric sulphocyanide produced. Prussic acid, faintly acid, leaves no residue on Platinum; is readily distilled.

THE END.

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